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THE SCIENTIFIC MONTHLY

AUGUST, 1918

THE MECHANISM OF LIGHT EMISSION

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IN THE SCIENTIFIC MONTHLY for February, 1917, Professor Guthrie gave an interesting account of the development of the electromagnetic theory of light. He explained how it had been demonstrated that light waves are very short electric waves similar in all respects except size to the electric waves used in wireless telegraphy. The latter are emitted from conductors of finite size in which electric charges oscillate, and may be several miles in length; the former are radiated from small negatively charged particles called electrons vibrating in molecules or atoms, and are measured in millionths of a millimeter. So far as the theory of light transmission is concerned, there is reason to believe that our knowledge has approached finality. There seems to be no acceptable alternative to the conclusion that light is due to wave motion in the hypothetical medium called the ether, concerning which we may never know more than we do now, but which it seems necessary to postulate as the seat of electrical and magnetic phenomena.

We may, however, hope to learn much more than we now know concerning the processes in matter which cause the radiation and absorption of light. Under the term light, we must include the invisible radiations which lie on both sides of the narrow range of frequencies or wave-lengths which are included in the visible spectrum—the short ultra-violet and X-ray radiations on one side and the longer infra-red waves, often mistakenly called heat waves, on the other. Electromagnetic theory and the effect of a magnetic field on radiating sources (the Zeeman effect) make it certain that the shorter light waves, at least, are set up by the periodic displacements of

electrons in the atom. The frequencies of vibration must be determined by the forces in the atom due to the number and arrangement of the positive and negative charges in it, hence the problem of radiation is intimately connected with that of atomic structure, and this in turn with all the properties of matter; and it is also dependent upon the relationship between matter and ether which makes possible the interchange of energy between the two. Hence the mechanism of radiation is a subject of great importance—in fact, probably the most important and the most interesting of the problems which confront the physicist to-day.

Some general facts concerning radiation are familiar to all. We know that most luminous sources are very hot—red-hot at a moderate temperature, white-hot, that is to say emitting all colors, at very high temperatures. From this we may infer that heat is the cause of radiation in such cases, and that the colors emitted depend upon the temperature. Since heat is energy of molecular motion, we might jump to the conclusion that the agitation of the molecules sends out waves in the ether just as the jumping of a trout sends out waves in water. But unfortunately such a simple explanation seems insufficient, for a high temperature is not in all cases necessary to produce luminosity. The reader may recall some familiar illustrations of light emission by sources which are not hot. Many substances phosphoresce brightly at ordinary temperatures or even at such low temperatures as that of liquid air. The glowworm emits light of colors which are not radiated by carbon or a metal until it reaches white heat. The aurora glows brightly in the atmosphere at elevations where intense cold prevails. On the other hand, air and many other gases and vapors do not emit visible radiation even when heated to the highest degree. It is evident that other causes than energetic molecular motion may cause radiation. Our next inference might be that light is due to the vibrations of atoms within molecules which may not themselves possess much translatory energy, but this hypothesis proves insufficient in the case of monatomic gases, such as helium and mercury vapor. There seemed to be no explanation possible so long as it was assumed (without any rational basis, as we now see) that the atom is indivisible and unchangeable. No progress was possible until the discovery of the electron and of the atomic disintegration characteristic of radioactive processes proved the complexity of atoms.

In general luminous sources emit waves of many different

lengths and frequencies of vibration, each frequency corresponding to a different color. In order to analyze the light into its components, which is the first step toward obtaining a definite knowledge of what takes place in the source, the use of some form of spectroscope is necessary. What follows will be made clearer by the description of a simple form of spectroscope, to recall to the reader how the light is analyzed and what is meant by the "lines" of a spectrum. The light from the source is focused on a narrow slit, through which it passes in a divergent beam. A lens placed in this beam forms an image of the slit on a screen placed at the proper distance. If a prism is introduced into the path of the light, the beam will be refracted toward the base of the prism, and the deviation will be different for each color. If only one color (frequency) is present in the light, a single refracted image of the slit, of that color, may be thrown on a screen or a photographic plate. If two or more colors are present, there will be two or more images of the slit in different positions. These slit images are known as spectral lines. If the light is white, there will be an infinite number of slit images, corresponding to the infinite number of shades of color in white light, forming a continuous spectrum. If certain colors are removed by placing color screens in the path of the light there will be gaps in the spectrum, called absorption lines, corresponding to the absent slit images. Incandescent solids all give continuous spectra, with radiations extending beyond the red, and also beyond the violet at very high temperatures. Luminous gases and vapors, however, do not usually emit all colors, but only a finite number, giving rise to a corresponding number of bright lines. A series of observations by many investigators, and finally the work of Kirchhoff and Bunsen, about 1859, resulted in the recognition of the capital fact that no two elements have the same spectrum, that is, lines corresponding to each other in number and position. This makes the spectroscope an important instrument for the identification and discovery of elements in terrestrial and celestial sources, and serves also the important purpose of giving us significant data for the study of atomic structure and the relation between matter and ether which causes the emission and absorption of radiant energy.

In 1814 Fraunhofer, an optician of Munich, observed that there are many dark lines in the spectrum of the sun. The explanation was found, but not fully grasped, by Foucault in 1849, who discovered that a pair of very close dark lines in the

solar spectrum corresponded exactly in position with two bright lines emitted by luminous sodium vapor, and that if sodium vapor is placed in the path of white light the vapor absorbs the same colors, giving rise to dark lines like those in the solar spectrum. Sodium vapor in the sun's atmosphere causes these lines. Later investigation has shown that many thousands of lines in the solar spectrum correspond in position with the bright lines emitted by a number of metallic vapors, which proves that these metals exist in the sun. Further investigation has confirmed the fact that the vapors of many elements will absorb some at least of the colors which they emit when luminous. Stokes, the English physicist, pointed out the acoustical analogy. Sound waves from a tuning fork will cause a neighboring fork of the same frequency to vibrate, but will have no effect on a fork of a different frequency, and a large number of such resonating forks would form an effective screen to the sound waves by thus absorbing their energy. This suggested the possibility of a further acoustical analogy. A tuning fork emits sounds of but one frequency (analogous to the unknown case of a luminous substance emitting but one color of light), but most musical instruments, such as pianos and organ pipes, emit simultaneously a number of sounds of different pitch. The overtones emitted by a piano wire or an organ pipe always have frequencies which are simple multiples of that of the fundamental tone. If the same were true of light sources, the wave-lengths of the lines of a given element should be simple fractions of the length of the longest wave. This is not true in any case. Some elements, such as iron or uranium, have thousands of lines, chaotically arranged, so that the emission centers not only radiate a wider range of frequencies than is emitted by a piano when its entire keyboard is struck, but none of the simple numerical relationships between the frequencies are found, as is the case with the piano. It is inconceivable that any simple body, such as the hypothetical round, smooth, hard atom of kinetic theory, could emit such a complex system of radiations. There is no escape from the assumption that the atom is a very complex body, not the ultimate indivisible unit of matter which it was once, without proper foundation, supposed to be.

The first step toward a definite theory of atomic structure which would help to explain the facts consistently was the discovery by Zeeman in 1896 of the effect of a magnetic field on a radiating source. He found that if a flame colored with

sodium is placed between the poles of a strong electromagnet, when the latter is excited each spectral line, when viewed at right angles to the field, is split into three components, which are plane-polarized. When viewed in a direction parallel to the field, each line is split into two components, which are circularly polarized in opposite directions, that is to say, the ether motion is like that of right- and left-handed vortices. H. A. Lorentz, of Leiden, pointed out that he had developed a theory which would explain this phenomenon, based on the assumption that light emission is due to vibrations or revolutions of small electrified particles in atoms. In the absence of a magnetic field the displacements would be in all directions (unpolarized) and all of the same period. In accordance with familiar electro-magnetic laws, the magnetic field will retard the motion of the particles moving in one direction, will accelerate the motion of those moving in the opposite direction, and will have no effect upon motions parallel to the field. Thus the three plane-polarized components are accounted for, and also the circular polarization of the doublet, this being merely the ether vortex motion viewed end on. Quantitative measurements showed that these particles are negatively charged and have a mass about one eighteen-hundredth that of a hydrogen atom. This identified them with the cathode corpuscles, the nature of which had been discovered by J. J. Thomson shortly before. These small particles, to which the name electron has been given, are likewise discharged from negatively charged metals when illuminated by ultra-violet light, and from incandescent metals. They are apparently constituents of all substances, and play an important rôle in many physical phenomena.

The radiation from incandescent solids is undoubtedly due to the displacements of the electrons in the atoms, but these atoms are crowded so closely together and their agitation at high temperatures is so chaotic that it is difficult to picture exactly what is going on or to account for the wide range of vibration frequencies—practically an infinite number—represented in the radiation. Spectroscopic observations show that the spectra of all incandescent solids are identical in the sense that they are continuous and that the relative intensities at different wave-lengths are the same for all sources at the same temperature. As the temperature rises the intensity increases for each wave-length, but more rapidly for the shorter waves, the limit of which creeps toward the violet as the temperature rises. All solids above absolute zero emit radiations giving a

continuous spectrum. The spectrum of a cold body, such as ice, lies entirely in the infra-red. The shortest waves emitted by a piece of red-hot carbon are red, the other colors appearing in succession as the carbon becomes white-hot. It is evident from these facts that a large proportion of the radiation from any solid source lies in the infra-red and is useless so far as illumination is concerned, and that the useful fraction increases with the temperature. From the nature of the case, it is impossible to avoid this waste in the use of any solid source. One of the great practical problems awaiting a satisfactory solution is the discovery of vapors or gases which may easily be made luminous by the electric current and which will emit radiations lying mostly in the visible spectrum. The mercury lamp is the most successful of this type so far discovered, but the disagreeable color of its light prevents its extended use. Various more or less empirical laws concerning the distribution of intensity in continuous spectra have been found, and some success has been obtained in correlating these laws with general theoretical principles. Planck has in recent years deduced the most successful formula for the distribution of energy in the spectrum of a black body, based partly on the laws of probabilities and of thermodynamics and electromagnetism, partly on the bold assumption that energy can not be radiated in a continuous stream, but only in definite units, the magnitudes of which are proportional to the frequencies of vibration, the proportionality factor being known as Planck's "wirkungsquantum *h*." He assumes that the radiation is due to atomic oscillators, the electrons, but he has not explained how these electrons can have such a wide range of frequencies or given any definite physical reason why the "energy quantum" law should hold.

In the present state of our knowledge it is hardly worth our while to discuss the radiation of solids or the quantum theory further, but in considering the simpler case of the radiation of gases and vapors we shall find that experimental facts suggest some definite conclusions which may serve as the basis of plausible theories. The first of these, which goes back to the early days of spectroscopy, relates to the nature of the emission centers of the two types of discontinuous spectra, bands and lines. In the latter the lines are generally at some distance apart and arranged irregularly, although in some of the simpler spectra groups of lines ("series") have been found which are arranged with some regularity and are connected by more or less simple mathematical relations. Bands are composed of

groups of lines, those in each group very close together and at intervals which increase regularly in going from the well-defined limit called the "head" of the band, where the lines are most intense, and closest together. It was found by Mitscherlich about 1862 that many compounds, such as calcium oxide, when made luminous by a flame or a feeble electric discharge give characteristic band spectra, hence such spectra must be due to the undissociated molecule of the compound. Very intense electric discharges will in every case cause these bands to disappear and the lines of one or both the constituents of the compound to appear. It has since been found that many elements also, such as nitrogen, iodine and carbon, give band spectra when excited by a feeble electric discharge, but line spectra with the more intense discharges which may be assumed to dissociate the molecules into their constituent atoms. From such evidence we may feel fairly certain that luminous vapors in the molecular state, whether elements or compounds, give band spectra, while emission centers in the atomic state give line spectra. Some vapors, however, which certainly have monatomic molecules, such as mercury, give band as well as line spectra, so that we are compelled to look for a further ground of differentiation. The most obvious is to assume that the difference is due to the electrical state of the particle. For example, it may be that band spectra are characteristic of uncharged molecules, whether monatomic or polyatomic, while line spectra may be due to charged atoms, or ions, the charges arising from the loss or gain of electrons. There is direct experimental evidence which favors this view, although this evidence is sometimes ambiguous.

Lockyer was the first to call attention to the fact which is now evident to all observers that spectra are not the unchangeable things they were at first supposed to be. For example, a metal vaporized in a hot flame may have a simple spectrum containing relatively few lines in the hottest part of the flame, while in the green cone, which is not at such a high temperature, but where great chemical activity and a greater degree of ionization exists, a larger number of lines may be observed. The arc spectrum of a substance contains still other lines, while the spectrum of the spark discharge between terminals of the same metal usually contains many lines which do not appear in the arc spectrum, and some arc lines may be suppressed. In general, with changes in vapor density, pressure, temperature, or the mode of excitation, lines belonging to one group may

weaken or disappear, others may be strengthened, and new lines may appear. It is evident that significant changes take place in the emission centers, and that, since radiation is an electromagnetic process, these effects must be due to changes in the electrical condition of these centers. Lockyer advanced the revolutionary hypothesis that the energetic excitation due to very high temperature or intense electrical discharges might cause dissociation of the atoms into basic elements, but until the discovery of the electron such a hypothesis could not be reconciled with accepted views.

Some general inferences regarding the electrical state of the emission centers may be derived from familiar facts. When a feeble electric discharge is passed through some compound vapors, such as those of the halogen compounds of mercury, a band spectrum is obtained which is characteristic of the compound, so that the emission centers are certainly the molecules. At the same time the conductivity of the vapor for the electric current shows that there has been some kind of ionization, or separation into charged components, and apparently the only way that this can happen is by the splitting off of electrons from the otherwise unchanged molecules. The emission must accompany either the separation or the recombination of the electrons. Luminous vapors giving band spectra appear, from their conduct in an electric field, to be uncharged, hence we may infer that usually band spectra are emitted during the process of neutralization accompanying the return of an electron. Again, the conduct in an electric field of vapors giving line spectra indicates that they are always positively charged. Phenomena previously referred to indicate, however, that groups of lines which behave differently with changed physical conditions must be due to different types of emission centers. If the emission centers are positively charged atoms, the only possible differences would appear to be in the magnitude of the residual positive charge, due to the loss of one, two, or more electrons. Some light has recently been thrown on this subject by researches on "positive" or "canal" rays, especially by those of Stark and of J. J. Thomson. The spectrum of a gas is usually obtained by passing an electric discharge through it when it is sealed at low pressure in a "vacuum" tube. If a hole is drilled through the negative electrode (the cathode) it is found that at very low pressures a luminous beam is projected through this opening on the side opposite the positive electrode. This beam is deflected by electric and mag-

netic forces, and from the magnitude and direction of this deflection it may be determined from elementary electrical laws that the luminous particles are positively charged and that they are of the magnitude of the molecules or the atoms of the enclosed gas. It appears that the positive ions in the conducting gas are accelerated by the strong electric field near the cathode, are projected with great velocity through the hole, and by collisions with the molecules of gas on the other side are excited to luminosity and excite luminosity in the stationary gas. From Thomson's researches it appears that, with few exceptions, no molecules carry a negative charge, or more than one elementary positive charge. Very few atoms acquire a negative charge, but they may acquire several positive charges. Stark arrived at similar conclusions by a spectroscopic method, which gave definite information regarding the number of positive elementary charges carried by emission centers giving different groups of spectral lines. In some cases more than one interpretation is possible, but in general these results are in harmony with the view that band spectra are emitted by neutral molecules or atoms—line spectra by positively charged atoms; that the emission centers of arc and flame lines are singly charged atoms; that the enhanced or spark lines are due to emission centers having two or more elementary charges. Thus we find substantiation for Lockyer's early views. There can be but little doubt that differences in line spectra are due to differences in the degree of electrical dissociation.

This raises the question of the number of electrons in a given atom and the number which it can lose. The greatest number of lost electrons shown by Thomson's experiments was eight, in the case of mercury, and usually it does not exceed three. Radioactive phenomena, however, give us reason to believe that the atoms of the heavier elements at least contain many electrons and also many separable and positively charged units. Uranium, for example, by the successive explosive losses of these positive particles (alpha rays) and electrons (beta rays) passes through the stages of ionium, radium, and the successive transformation products, and probably in the end becomes lead. Thus great complexity is certainly true of the radio-elements, and it is probably true of the elements of smaller atomic weight, which are either not radioactive or else disintegrate so gently and slowly that we have not discovered the fact. It seems reasonable to assume that the atoms of all elements, except possibly hydrogen and helium, which may be the

elementary units, are complex structures built of a number of positively and negatively charged particles, the number diminishing until we get to helium, which probably has a single alpha particle nucleus, and hydrogen, which probably has a single nucleus. The problem of atomic structure is concerned with the number and relative arrangement of these particles in the atom, and the problem of radiation with the causes and nature of the disturbances of the system which cause the emission of light waves.

If the electrons which emit radiation revolve in orbits about the atoms, as indicated by the Zeeman effect, the nuclei of the atoms must be positively charged in order to hold the electrons in their orbits; and if the emission centers are as a whole positively charged, one electron or more must have been completely detached from the system, while the radiation is due to those left behind. In order that these orbits may be stable, we must, in the light of our present knowledge, assume one of two hypotheses—the electrons must either be held in equilibrium at a definite distance from the center by some sort of elastic force which it is difficult to account for, or the velocities of the electrons and the radii of their orbits must be so adjusted that there exists an exact balance between the centripetal and centrifugal tendencies, such as that which prevails in the solar system. But if the electrons radiate they must lose energy, and if they lose energy they might be expected to fall into the nuclei as the moon would fall into the earth if it continuously lost kinetic energy. Either hypothesis involves difficulties. J. J. Thomson elaborated the idea that the atom is a sphere of uniformly distributed positive electricity, in which electrons are imbedded in such fashion as to be subject to quasi-elastic (but really electric) forces which cause them to vibrate when displaced. Opposed to this there is the Rutherford atom. The weight of experimental evidence, chiefly radioactive, seems to favor the latter. The alpha particles of radioactive substance, which after their positive charges are neutralized become atoms of helium, have an atomic weight four times that of hydrogen. They are projected from their parent atoms with tremendous velocities, and in their progress through air at ordinary pressures ionize from sixty to one hundred thousand molecules, producing twice as many ions, and yet they travel in almost perfectly straight lines, and only at the end of their path, where their velocity has been greatly reduced, do they show any marked evidence of deflection or reflection by impact with mole-

cules. The molecules of nitrogen and oxygen are about eight times as heavy as the alpha particles, and it is evident that if the latter struck these molecules squarely, as they must do to produce ionization of the Thomson molecule, they would be scattered in all directions. Such would not be the case with the Rutherford atom or molecule. In general the alpha particles go unimpeded through the open structure, usually missing the very small positive nucleus, but occasionally producing ionization by detaching electrons near which they pass. On rare occasions an alpha particle will go so close to the nucleus as to be subjected to a strong deflecting force, as in the case of a comet passing through the solar system and getting near the sun, only in the latter case the force would be attractive, while the positive nucleus will repel the positive alpha particle. These effects are shown clearly in photographs taken by C. T. R. Wilson of the path of alpha particles in air, the tracks being made visible by the trail of fog particles due to condensation of water vapor on the ions. Rutherford obtained further proof in favor of his hypothesis by measuring the angles of scattering of alpha particles passing through thin films of metals. In this case the scattering is greater than in air, because of the greater number of atoms encountered in a given distance and their greater mass. The relative number scattered at different angles can be exactly calculated on the assumption of a definite number of elementary positive charges concentrated in the nuclei of the atoms. The results show very conclusively that the number of these elementary charges, or more properly the excess of positive over negative charges, does not exceed half the atomic weight, the number growing relatively less with increased atomic weight—for example, as indicated in these and other experiments, the excess of positive charges in the nucleus of calcium, of atomic weight 40, is 20; in that of gold, of atomic weight 197, the number is 79. Space does not permit giving in detail the mass of evidence supporting this remarkable conclusion, but it seems convincing, and has already formed the basis of a new chemistry, in which the atomic number (the excess of positive charges in the nucleus) takes the place of atomic weight as the significant factor determining the chemical properties of the substance.

If we accept the Rutherford atom, it seems necessary to eliminate quasi-elastic forces and to assume that equilibrium of the electrons which must associate themselves with the nuclei to form neutral atoms is maintained solely by rotation in cir-

cular or elliptic orbits. The existence of a large number of electrons moving in such orbits increases the difficulty of accounting for equilibrium, particularly when we consider losses of energy by radiation, which should result in constant readjustments. Further, if uniform rotation is accompanied by radiation (as we might expect from electromagnetic theory) the atom should constantly radiate. Atoms do not normally radiate, however, but only when subjected to a violent disturbance which temporarily upsets equilibrium. We can readily account for three definite frequencies accompanying such perturbations of a single electron. Superimposed on the circular motion there might be vibrations radial, tangential, and normal to the orbit, and if uranium, for example, of atomic number 92, has 92 such electrons circulating about it we could account for 276 spectral lines in this way. As a matter of fact, uranium has many thousand lines in its spectrum, and it seems beyond the powers of the human mind, with our present knowledge, to imagine the atomic structure which would account for the observed facts and emit radiation in accord with the accepted laws of physics.

Bohr has formulated a hypothesis applicable to the spectra of hydrogen and helium in which he boldly departs from some of these laws. He accepts the Rutherford atom, and assumes that hydrogen has a simple nucleus of one positive charge about which a single electron revolves. According to accepted laws, which associate radiation of waves with accelerated motion of electric charges, the electron revolving in a circular orbit should emit waves, for it is subject to centripetal acceleration. Bohr assumes that this law does not apply within the atom, although the ordinary laws of electrical attraction hold the electrons in their orbits. A further radical assumption is that there are a number of possible "stationary" orbits, of different radii, in each of which the electron may move under conditions of equilibrium. An external disturbance may cause the electron to jump from one orbit to another, and during this transition radiation is emitted amounting to one of Planck's energy quanta, that is the difference between the kinetic energies of the electron in the two orbits is radiated with a frequency which is determined by the relation that the frequency multiplied by Planck's "wirkungsquantum," the mysterious constant h, is equal to this energy. There must be as many possible orbits as there are lines in a series. Bohr deduced an expression for the frequencies of the principal lines of hydrogen like Balmer's

empirical formula, which had been known for some time, and which expresses with great accuracy the positions of the lines in several series including the principal lines of hydrogen. With equal success Bohr applied his hypothesis to the case of helium, with two nuclear charges and two detachable electrons, one of the latter being detached, but he could not solve the problem in the case when both electrons are retained. The problem for other atoms is likewise too difficult to solve.

Some years ago Laue showed that the X-rays are diffracted in passing through the regular space lattice of atoms in a crystal, producing diffraction patterns on a photographic plate similar to those observed in looking at a distant light through a fine-meshed handkerchief. This proved that the X-rays are due to waves. The Braggs showed that these waves could be reflected from the atomic planes in crystals, and Moseley, by an ingenious application of this principle, was able to determine the lengths of the stronger characteristic waves emitted by different metallic targets when bombarded by cathode rays. He discovered the remarkable fact that the square roots of the frequencies of the principal lines are proportional to the ordinal numbers, increasing by unity in passing from one element to the one of next highest atomic weight. Siegbahn has extended Moseley's results to the heaviest element, uranium, with atomic number 92, and downward to sodium, of atomic number 11. The known elements of smaller atomic weight fill the remaining places down to hydrogen, of atomic number 1, and there are but six gaps in the entire series, to be filled by possible discoveries of new elements. These results are consistent with the numbers referring to nuclear charges determined by Rutherford and others. Bohr's theory likewise leads to the conclusion that the square roots of the frequencies should be proportional to the nuclear charges. Any single line of evidence suggesting these relations might be regarded as highly hypothetical, but the cumulative effect of several kinds of diverse experimental evidence is to produce a feeling of confidence amounting almost to certainty that the nuclear theory is correct, although there is still uncertainty as to the relations of the radiating electrons to the nuclei. If the frequencies of vibration of the electrons are proportional to their frequencies of rotation, which seems highly probable, the extraordinarily high frequencies of the X-rays, several thousand times greater than those of ordinary light, indicates that the emitting electrons lie in orbits very close to the nucleus and practically forming a part of it, which

are excited to radiation by displacements due to intense electron bombardment, while the electrons emitting ordinary light, in numbers sufficient to neutralize the charge of the atom as a whole, lie in orbits of relatively large radius. In both cases, if Bohr's hypothesis is correct, there are a number of possible orbits for each electron, and radiation is emitted only in passing from one to another. This hypothesis fits the cases of several groups of lines in the spectra of hydrogen and helium with astonishing accuracy, yet it leaves much to be explained and involves the acceptance of notions which, to say the least, are difficult to reconcile with principles which have seemed to us to be firmly established. In the case of such a simple structure as that assumed for hydrogen, how can we account for the number of stationary orbits demanded? What determines the frequency of the radiation emitted when an electron passes from one orbit to another? It would seem to be necessary for the electron to know in advance what orbit it will finally adopt. How shall we account for the thousands of other lines in the spectrum of hydrogen which the hypothesis fails to account for, and for the continuous spectrum? These things seem to demand a greater complexity than that assumed by Bohr. Stark has lately found that the spectral lines of hydrogen and of a few other elements are split up into many components when the radiating gas is in a strong electric field, in such a way as to strengthen the suspicion that more than one electron takes part in the radiation. It does not seem impossible that the nuclei of both hydrogen and helium may be built up of smaller positive units than the alpha particle and the assumed simple hydrogen unit, with electrons combined with them, so that the resultant nuclear charges are respectively 1 and 2. So far, however, there is no experimental evidence pointing to the existence of a smaller positive electron than the hydrogen nucleus.

There is another possibility which can not be overlooked, although there is little experimental basis for any clear-cut hypothesis—a static atom, that is, one in which the electrons are normally at rest in a condition of static equilibrium, held in place by quasi-elastic forces which set up vibrations when the electron is slightly displaced. Such an atom would probably better suit the chemist than the Rutherford atom, for how can we imagine two atoms in which the outer rings of electrons, the "valency" electrons, are in rapid rotation, ever entering into permanent relations with each other in the molecular state?

But we are unable to account for such quasi-elastic forces in the open structure demanded by radioactive phenomena, and it is impossible to imagine electrons stationary in space, with nothing to hold them apart from the neighboring attracting positive charges.

It is evident that we have far to go to reach a complete explanation of light emission, but the experimental developments of the past few years, the circumstantial evidence based on many different lines of attack, give us reason to hope that we may solve the problem qualitatively at least, that is, decide definitely between the Rutherford and the static atom, and possibly in the simpler cases, such as that of hydrogen, arrive at a fairly complete solution of the problem. A complete quantitative solution of the general problem we can hardly expect. The astronomer can not solve the problem of three bodies in such a system as that of our sun; how can we expect to solve the far more difficult problem of the motions of the swarm of mutually attracting and repelling particles in the atom?

THE STATUS OF SEALING IN THE SUB-ANTARCTIC ATLANTIC

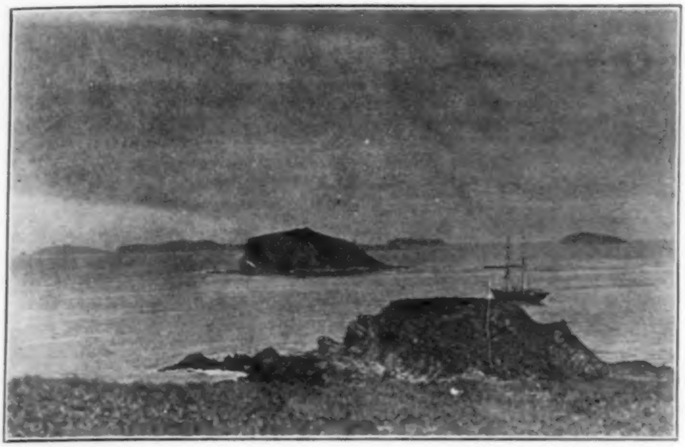
By ROBERT CUSHMAN MURPHY

BROOKLYN MUSEUM

SEALING on the coast of Patagonia, the Falklands, and the islands north and east of Cape Horn began during the third quarter of the eighteenth century. Alexander Dalrymple, writing in 1775, reports that there was at the Falklands an abundance of "Sea-Lions[1] 25 feet long and 19 to 20 round," and also fur seals in "such numbers that they killed eight or nine hundred in a day with bludgeons on one small Islot." Shortly after the American Revolution, New England and British sealers extended their hunting still farther afield, at first to South Georgia, twelve hundred miles east of Cape Horn, and then to the South Orkneys and South Shetlands, well beyond the sixtieth parallel.

The naturalist George Forster, who accompanied Captain James Cook on his renowned voyage toward the South Pole in the year 1775, had written prophetically of the possible exploitation of South Georgia, although even his farsighted imagination had failed to picture the rapid strides which adventurous commercialism would make. "South Georgia," wrote Forster, "besides being uninhabitable, does not appear to contain any single article, for which it might be visited occasionally by European ships. Seals, and sea-lions, of which the blubber is accounted an article of commerce, are much more numerous on the desert coasts of South America, the Falklands, and the New Year's Islands, where they may likewise be obtained at a much smaller risk. If the northern ocean should ever be cleared of whales, by our annual fisheries, we might then visit the other hemisphere, where these animals are known to be numerous. However, there seems to be little necessity to advance so far south as New Georgia in quest of them, since the Portuguese and the North Americans have of late years killed numbers of them on the coast of America, going no farther than the Falkland Islands. It should therefore seem probable, that though Southern Georgia may hereafter become important to mankind, that period is at present so far remote,

[1] Sea-elephants (*Mirounga leonina*).



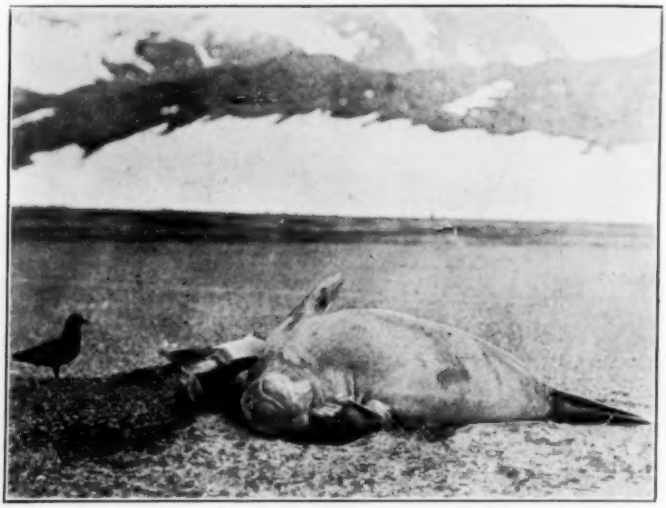
Photographs by the Author.

An American Sealing Vessel, the brig Daisy, of New Bedford, Mass., at anchor in the Bay of Isles, South Georgia. In the foreground is a wandering albatross (*Diomedea exulans*) upon its nest.

and perhaps will not happen, till Patagonia and Tierra del Fuego are inhabited, and civilized like Scotland and Sweden." Forster's reference to the possibility of the northern ocean being "cleared of whales" indicates at least that he was not obsessed by the "fallacy of the inexhaustible."

Scarcely a quarter of a century after Forster's visit, sealing at South Georgia had reached its height, and in 1800 Captain Edmund Fanning in the *Aspasia* of New York, one of eighteen sealing vessels at the island, secured the season's prize

American Sea-elephant Hunters at work at the head of Possession Bay, South Georgia, March, 1913.



A "Cow" and a "Pup" Sea-elephant sleeping at the Bay of Isles, South Georgia, December 30, 1912. Both animals are characteristically scratching, or brandishing their flippers. The bird is a skua gull (*Catharacta antarctica*).

catch of 57,000 fur seal skins. This record was never again equaled, although the hunting evidently continued, for, when the Russian explorer, Bellingshausen, sailed along the blustery, uncharted south coast of the island in December, 1819, he met with two English three-masters in one of the fjords. These ships had already been there four months, or through the southern winter, and had carried on a profitable business. But when James Weddell, less than five years later, came to South Georgia, he found that seals of all kinds had become "almost extinct." Weddell's account contains much historical information, and the following portion is well worth quoting:

[Cook's] official report regarding the island of South Georgia, in which he gave an account of the great number of sea-elephants (called by him sea-lions), and fur seals, found on the shores, induced several enterprising merchants to fit out vessels to take them: the elephants for their oil, and the seals for their skins. These animals are now almost extinct; but I have been credibly informed that, since the year in which they were known to be so abundant, not less than 20,000 tons of the sea-elephant oil has been procured for the London market. A quantity of fur seal skins were usually brought along with a cargo of oil; but formerly the furriers in England had not the method of dressing them, on which account they were of so little value, as to be almost neglected.

At the same time, however, the Americans were carrying from Georgia cargoes of these skins to China, where they frequently obtained a price of from 5 to 6 dollars a-piece. It is generally known that the Eng-

lish did not enjoy the same privilege; by which means the Americans took entirely out of our hands this valuable article of trade.

The number of skins brought from off Georgia by ourselves and foreigners can not be estimated at fewer than 1,200,000.

Of seals at the South Shetlands, where Weddell's two crews killed "upwards of 2,000" sea-elephants during the same voyage, the sagacious mariner writes in an economic vein worthy of a later age:

The quantity of seals taken off these islands, by vessels from different parts, during the years 1821 and 1822, may be computed at 320,000, and the quantity of sea-elephant oil, at 940 tons. This valuable animal, the fur seal, might, by a law similar to that which restrains fishermen in the size of the mesh of their net, have been spared to render annually 100,000 furs for many years to come. This would have followed from not killing the mothers till the young were able to take the water; and even then, only those which appeared to be old, together with a proportion of the males, thereby diminishing their total number, but in slow progression.

Since 1825 fur sealing at the southern Atlantic islands has been a decadent commerce. As the prey became scarcer, the brave fleets of the early days gave way to lonely, prowling schooners which poached from the fur seal rookeries of the Falklands, or reaped the meager harvest of a few seasons' repletion at South Georgia. Fur seals are believed to have been practically exterminated at the latter island about 1874, but rumor has it that a New England vessel made a small, illegal catch there in 1907. About the middle of February, 1915, some Norwegian whalers discovered a single fur seal on the beach near the eastern end of South Georgia. This forlorn veteran was promptly knocked on the head, and so the tale ends.

A Bull Sea-elephant swimming away from the observer, and about to enter the kelp fields of the Bay of Isles. South Georgia, January 6, 1913.

A NEW BEDFORD SEALER ABOUT TO LANCE A BULL SEA-ELEPHANT AT THE BAY OF ISLES, 1912, and March 14, 1913. 1,641 sea-elephants were killed at this island by the crew of a single American sealing vessel.

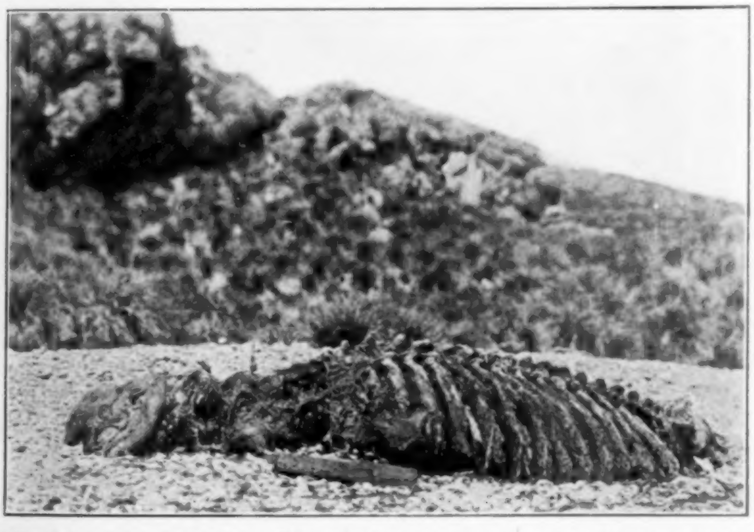
The story of the sea-elephant is not unlike that of the fur seal. The species was cleaned out successively on the South American coast, the Falklands, Tristan da Cunha, and the South Orkneys and Shetlands. At South Georgia persistent killing pushed it so near the verge of utter extinction that in 1885 the crew of a Connecticut schooner during ten weeks of the breeding season (September to January) was able to find only *two* of the animals. From before that date, however, until after the beginning of the twentieth century, the seat of the "elephant oil" traffic was transferred from the south Atlantic to the fresher islands of the Indian Ocean, and so the species was given an opportunity partially to regain its foothold at South Georgia. During the last few years hunting has been resumed there, not only by occasional sailing ships from American ports and elsewhere, but also by one of the South Georgia whaling companies, which, through the employment of steam vessels and highly efficient methods, has made extensive inroads upon the male sea-elephants after the end of the breeding season, as many as 6,000 bulls having been killed during one summer.

In taking sea-elephants, the hunters plan first to drive the animals as near to the water as can be done without risk of their escaping. After this they are clubbed, lanced, or shot, or all three if necessary. Sometimes they can be frightened and sent bounding toward the sea by the sound of small stones rattled in an iron pail. If, however, they prove too sluggish or

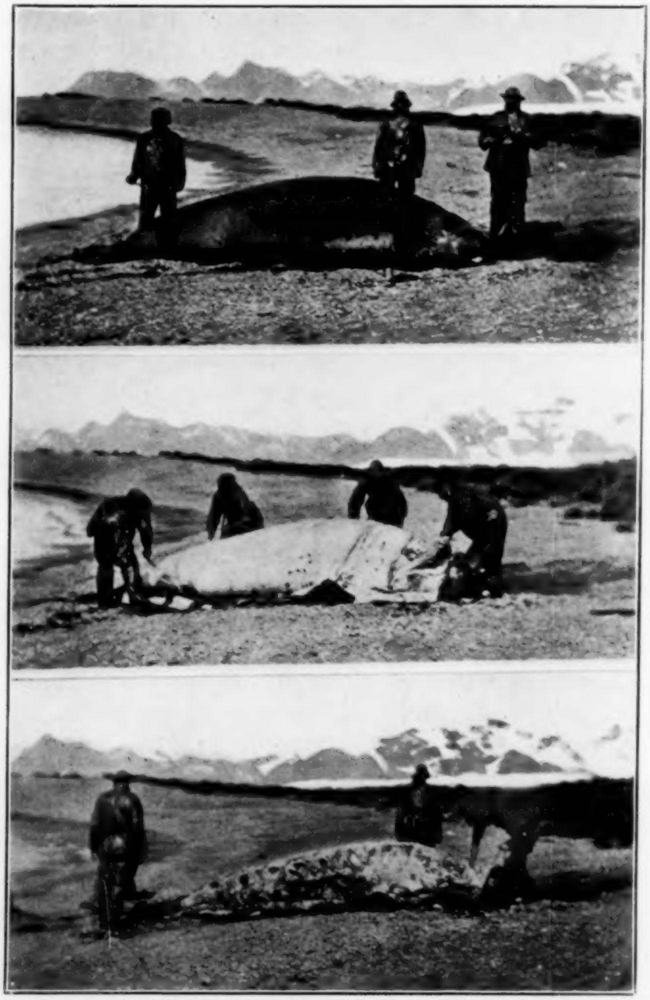
refractory they are often treated with the most revolting brutality; anything seems to be permitted which will urge them beachward and so lighten the labor of carrying blubber.

The old American method of utilizing the blubber is wasteful in every stage. After the slain "elephant" has been allowed to bleed thoroughly, the hide is slit lengthwise down the back, and then transversely in several places from the dorsal incision to the ground. The flaps of hide are next skinned off, and the remaining investment of white blubber, which may have a maximum thickness of about eight inches, is dissected away from the underlying muscle and cut into squarish blanket-pieces. The animal is then rolled over and the same process repeated on the ventral side. Thus the hide, and the considerable amount of blubber which clings to it, are lost at the start.

The blanket-pieces of the blubber are hauled to the water's edge to be strung on short ropes called "raft-tails." These are towed to the anchored ship where each laden raft-tail is looped about a hawser which extends from bow to stern, and the blubber is permitted to soak for forty-eight hours, or thereabouts, until the red blood corpuscles have been practically all washed away. During the soaking process a certain proportion of the oil is lost, and, moreover, flocks of ravenous "Cape pigeons" (*Petrella*), and other ubiquitous sea birds, feed upon the floating fat with an interminable hubbub, both night and



THE STRIPPED CARCASS OF A SEA-ELEPHANT, WHICH HAD BEEN KILLED ONE OR MORE YEARS EARLIER, lying on the South Georgian beach. Thousands of seal remains, in all stages of slow decomposition, tell of the former slaughter and of the wasteful methods.



THE THREE STAGES IN THE DISPOSAL OF A SEA-ELEPHANT, according to the method of the American sealers. The upper photograph shows a bull sea-elephant which was lanced by the writer at the Bay of Isles, South Georgia, on February 17, 1913. The second picture illustrates the removal of the hide, which is cut off in small flaps, leaving the blubber exposed. A curved knife with an eight-inch blade is used in skinning, and, by means of a long, sweeping stroke, the hide is cut away as closely and cleanly as possible. The lower picture shows the carcass completely stripped of its dorsal blubber, which has been dragged to the adjacent cove. The carcass is now ready to be rolled over so that the hide and blubber of the ventral surface may be removed in the same manner. Photographs by Captain R. D. Cleveland.

day. When the blubber is hauled on board it is cut into narrow strips called "horse pieces," and is afterwards "minced." The mincing differs from the same process in sperm whaling only in that the fat is cut very finely with hand knives. At this stage

an additional loss of oil occurs, particularly if the temperature of the air chances to be well above the freezing point. Finally the minced blubber is "tried out" in the familiar deck try-works of the old whaling type. There is so little residue or "scrap" from boiled sea-elephant blubber that the Heard Island sealers of last century used to calculate "a cask of oil from a cask of blubber."

The method as practised by Norwegian whalers at South Georgia is more economical, inasmuch as the chunks of sea-elephant blubber are left attached to the skin, and loaded into a steamer's hold, after which the cargo—hide, fat, blood, dirt and all—is dumped into steam try-works at the whaling station and reduced to oil and slag.

During fifteen months of 1914–1915, 850,000 gallons of sea-elephant oil are said to have been exported from South Georgia by the Norwegian whalers. The sea-elephants can not long withstand such a toll as that, and the question as to whether the magnificent species is to be perpetuated will depend upon protective legislation which, it is to be fervently hoped, the British government will see fit to enact after the war. The difficulties and expenses of the modern whale fishery at South Georgia make it almost impossible for any species of whale to be completely extirpated, however persistently it may be chased, but the unfortunate sea-elephants have no such hope of preservation. Slow, unsuspicious, gregarious, they can be hunted profitably until the last one has gone to his ancestors and the tragedy of the antarctic fur seal is repeated.

PRINCIPLES AND PROBLEMS OF FISH CULTURE IN PONDS

By DR. R. E. COKER

ASSISTANT IN CHARGE SCIENTIFIC INQUIRY, U. S. BUREAU OF FISHERIES

FISH as living animals have essentially the same general requirements for growth and propagation as poultry or pigs. As animals living in water, however, they present their needs to us in a so much more obscure way that our problem in providing the proper conditions is relatively complex. We have to meet most of the requirements for successful rearing of fish by very indirect means, and in so doing we have to be guided by a knowledge of general principles and the application of common sense, rather than by any explicit rules.

The ordinary needs of fish, flesh or fowl are: air, water, food, cleanliness, exercise, shade, protection of adults and young from enemies and disease, some control of numbers in proportion to available space, proper conditions for breeding, and care of young. Looking at these requirements severally, we are at once confronted with a striking point of difference between fowl culture and fish culture. *Air*, or more strictly *oxygen*, is freely supplied by nature to animals. With the fish the oxygen problem is paramount, and the fish-farmer must give first thought to the maintenance of a favorable oxygen supply in his pond. Without food the fish would live for days or weeks; without oxygen, it would suffocate in a few hours.

OXYGEN

Here is an excellent illustration of the fact that many of the requirements of fish are supplied by indirect means. Before we can proceed intelligently, we must know how the fish gets the oxygen necessary for its existence, that is to say, by what processes the oxygen supply is maintained in a natural body of water. This is one of our problems in its broad aspect.

Two processes are continually depleting the oxygen supply: The respiration of animals and the decomposition of various materials. In warm weather, too, the water will hold less oxygen, and it is accordingly the more necessary that the supply of oxygen shall then be added to continuously and abundantly.

How is the supply of oxygen maintained in a body of water? There are two principal means, one of which takes care of itself, but which is not entirely adequate for the purpose in small bodies of water.

First we are concerned with the interchange of gases between the surface of the water and the air. Birge has aptly employed the term "respiration of lakes," suggesting that the lake or pond breathes through its surface. He and others have shown how the oxygen supply thus derived is distributed through the body of the lake, and how this distribution is affected by temperature, seasons, winds and other factors.

As regards the propagation and rearing of fishes in self-contained ponds, we are led at once to certain very practical questions. What should be the size, the form, the depth and the relative proportion of deep and shallow waters in the several units of our pond system, or of our single pond if there can be but one? Obviously, for a wintering pond we must provide for storage of oxygen to carry over the winter; but in spring, the season of renewed activity, spawning, and the beginning of life for a new generation, the deep winter pond, now depleted of oxygen, proves ill-adapted for quick recuperation, since the warmer surface waters fail to carry the absorbed oxygen to the bottom. This is the season when the natural ponds and streams are accustomed to broaden their margins and flow out over the surrounding lands, and most of the fish in spawning activity are observed to follow the waters outward and to deposit their eggs in places more or less removed from the customary banks of the stream or pond. They find inducement to this outward migration, perhaps, in the warmer temperatures prevailing in the shallow overflow waters, or, perhaps, in the better conditions of oxygenation which may prevail at least temporarily.

Since it is being attempted to suggest rather than to outline problems, it may be in place to mention without comment two unrelated, but very interesting, facts. It is in the middle or late spring that the Bureau of Fisheries expects and receives the most numerous reports of unexplained mortalities of fishes in closely confined lakes. The other interesting fact is this: For two years, at our Fairport station, the effort to get the buffalo fish to spawn in artificial ponds failed. Last year, Mr. A. F. Shira, the director of the station, made the experiment of causing the pond to flow out gradually over a considerable area of ground just as the temperatures were developing when

Part of a group of ponds for fish-culture experimental work, at the United States Fisheries Biological Station, Fairport, Ia.

spawning could be expected. The buffalo fish acted just as they do in nature; they moved out into the shallow waters and spawned—doubtless the first buffalo fish to spawn in controlled ponds. Whether temperature or oxygen supply, or both, or something else is responsible for phenomena such as these, it is evident that the fish-culturist must look to the student of the physical conditions of enclosed waters for guidance in the construction and the control of ponds.

Just as the trees and the small plants and the grass are continually breaking up noxious gases in the air and replenishing the supply of oxygen, so in the water the submerged vegetation plays an important part in maintaining the oxygen supply for fish. In fact, they are probably the principal dependence for oxygen in ordinary fish ponds. In a very large lake where there are high waves and pronounced wind-driven currents, rolling movements, and upheavals, the vegetation plays a less part. The smaller the pond, however, the more essential are the submerged plants. Plants serve another useful purpose in taking care of the noxious carbon dioxide which is given off by animals in breathing and which is formed by the processes of decomposition.

In selecting plants for the pond for the purpose of oxygenation, it must be kept in mind that plants do not possess this function except in the presence of sunlight. The large lilypads which are so esthetically pleasing, but which, being at the surface, can contribute little to the oxygen supply of the water,

form a deep shade that must diminish the oxygen-producing capacity of other plants living in the water beneath. It is evident that submerged vegetation is wanted and preference may be given to those plants having an abundant growth of narrow leaves, or to those with foliage so finely divided as to be needle-formed or brush-like. Consideration must be given, too, to the species which remain green during the winter or which are the earliest to give rise to new growth in the spring, so that there may be the most effective production of oxygen at a time when it is so important to the breeding fishes, and when the surface absorption of oxygen is normally less adequate.

Here, then, is a problem which has scarcely been attacked. What species of plants are the most effective oxygenators, under different conditions and at different seasons? The experienced and observant fish-culturist has somewhat definite ideas, and his judgment in the matter is very valuable, but I think that very little has been done in the way of experimental determination of the questions just stated. We ought to know, as precisely as we can, the relative oxygenating values of the different species of aquatic plants—for wintering ponds, for spawning ponds, and for rearing ponds.

Food Supply

The fish must have food and, under ordinary conditions of fish-culture, the food naturally produced in and about the pond is the principal dependence. Obviously, the productiveness of a pond in fish is directly limited by its productiveness in food;

An Experimental Pond, maintained under the conditions of a farm fish pond.

hence, fish-culturists often say that the whole problem of fish culture is one of food supply. It may well be so, since this is not a single problem, but a complex of problems.

Biologically speaking, the food problem starts with the plants, as the source from which, or through which, all animal food must come. Plants form the basis of food supply—large plants or microscopic plants, green plants or dead plants, or the finely divided plant remains constituting the detritus. To what extent do plants, living or dead, enter directly into the food of fishes? I venture to say that we know yet very little of this. Only a few years ago, the forage value of plants was considered insignificant. Yet, very recently, an investigator associated with our Bureau, Dr. A. S. Pearse, of the University of Wisconsin, has prepared for publication a report of the food of 32 species of fish from lakes in Wisconsin, and, from one of his tables, it can be found that, with 23 species, plant remains or algae constituted an appreciable portion (one per cent. or more) of the stomach contents, ranging from 1 per cent. to 25½ per cent. If we include silt and débris (probably plant material principally), 25 of the 32 species were plant feeders, and the ratio of such food to the total ranges from 1 to 40 per cent. Other uncompleted investigations of the bureau indicate that vegetable detritus constitutes a substantial, or perhaps the principal, element of diet for fresh-water mussels and for the young buffalo fishes. This is certainly true for many insect larvæ, and other small animals.

Undoubtedly, the direct food value of vegetation to pond fishes, especially to the young, is not inconsiderable; but even more significant is the part which this form of food plays in an indirect way. Generally speaking, as the fishes become older and larger (this is not true of all species, of course), they seek larger and more active prey, entomostraca are passed over for small insect larvæ, amphipods, small snails, etc., these in turn give place to larger insect larvæ, crawfishes and small fishes, and finally, larger fishes and frogs may become the special prey of the "big-game hunters" among the fish. But all the multitudinous members of this complex community of hunters and hunted derive their origin from plant matter. Now, one phase of this general problem of the relation of plants to food supply to which it is desired to direct attention is this: We have very little information as to the relative food values of the different species of plants. Undoubtedly, some species of plants are better forage plants than others. Dr. Emmaline

Moore, of Vassar College, and quite recently a special investigator for the Bureau, has already given us some valuable information about this, and I may be permitted to emphasize the point that, as her investigations show, plants of one species may be foraged upon, while those of a closely related species are left untouched. Presumably, too, some plants, when dead and disintegrated, give rise to a more palatable or nutritious detritus than others; of this we know little, if anything.

These questions of the relative values of plants, viewed either as oxygenators or as food makers, are not of theoretical or scientific interest only. This can be made clearer from an analogy. A stock farmer may have no interest whatever in plants as plants. Nevertheless, he sows alfalfa under certain conditions and burr-clover under others; he knows when and where he wants to plant red clover, and he knows that he never wants to plant sweet clover. All of these legumes are fairly closely related, yet the grower of stock has learned to discriminate between them, to use each to best advantage, or to let them alone, as his purpose may require. The grower of fishes, on the other hand, lets grow what will, practically speaking—and who can now advise him intelligently?

Our problem does not stop with the plants—it only begins there, biologically speaking. Small crustacea, insect larvæ, and molluscs feed upon plants or plant remains, and then upon each other. The problem becomes complex and peculiarly ecological, but its solution may be approached very directly. Here is an insect larva which feeds upon certain things and is preyed upon by certain other forms: it attacks and destroys small fishes and is itself devoured by larger fishes; it feeds upon materials which the fish that we wish to foster can not directly consume, thus adding material to the fish's food supply, while it competes with the fish for other forms and so diminishes the food supply; it destroys certain enemies of fishes, but who knows if it harbors some injurious parasite of fishes? The significance of this larva, and it is not altogether an imaginary one, is evidently not to be appraised as the result of casual observation. A great deal of data must be accumulated, the points of contact searched out in various directions, the evidence carefully analyzed, checked by experiment if possible, and weighed with sound judgment before a just conclusion is reached. Common sense will make the final ruling, but it will be common sense seated upon a secure bench of scientific observation and experiment. It would be an excellent thing for

fish culture if one after another of the typical inhabitants of a pond could be taken up for systematic study along such lines as have been suggested.

Since this paper must be kept within reasonable limits and as the ecological rather than the biochemic aspects of fish-cultural problems are primarily in mind, the important subject of the artificial feeding of fishes in ponds must be passed over at this time. More nearly ecological is the question of the fertilization of ponds—the adding to the water of organic or inorganic substances, so as to promote an abundant growth of desirable aquatic organisms, without impairment of the conditions of existence for fish. In this connection, I will merely hint at two very important subjects; that is, the character and composition of the bottom soils and the chemical composition of the water itself. We know that plants and animals have definite chemical requirements, and the requisite substances must come, directly or indirectly, from the soil or from the water. We strongly suspect, at least, that certain chemicals have subtle but significant physiological effects, favorable or unfavorable, upon the growth of aquatic plants and animals—effects that can be discovered not so readily by inference from analysis, as by experimental determination.

So far, we have kept strictly within the confines of the pond itself, but the ecological problems of fish culture extend well beyond the reach even of the highest waves that wash the margins. The sloping banks, the green sward, the meadows beyond, do not these contribute to the food supply of the pond? No one can be doubtful of this after walking around a pond, and noting the small frogs that leap from the banks to be snapped in by a hungry bass, or observing the grasshoppers and crickets resting on the lotus leaves or in the stems of *Persicaria* or of cattails, or watching the dragonflies and mosquitoes and dozens of other insects that pass from bush or grass to pond and back again (if luck is with them). Read the reports of stomach examinations by Forbes and others, and note the extent to which non-aquatic insects and other animals enter into the food of fishes. Mr. H. W. Clark, of the Bureau of Fisheries, tells of trout feeding upon masses of woolly plant lice as fast as they fell from overhanging alders. Professor C. B. Wilson, while working at the Fairport Laboratory, finds a certain dragonfly that, like others, through its larvæ supplies food to fish, but that almost invariably completed its metamorphosis on a hillside slightly removed from the pond, although in order

to arrive at this chosen environment after emerging from the pond, it was obliged to cross a dusty road. Professor J. M. Bates writes in *Science* of serious losses of fish in Pine Creek, Nebraska, caused apparently by feeding upon rose chafers dropping from overhanging willows. These are merely typical illustrations showing some of the various ways in which the land environment affects the fish life within the pond.

Doubtless, in due time fish farmers can be given definite and helpful advice, not only about the maintenance of a suitable environment in the pond, but also regarding the provision of a proper environment about the pond.

Association of Species

The judicious association of fishes within the pond is, perhaps, one of the most important questions of fish culture. To one who does not consider carefully the conditions of life in ponds, it may seem, offhand, that the only proper plan is one fish to the pond, yet, in all probability, this is rarely the practical plan of action. By associating two or more species of fish in the same pond, we expect to experience benefits in two directions: first—utilize the available space and food to best advantage, and, second—get the best results from any one given species.

There is nothing new in the idea that the appropriate association of species is for the best interest of the fish it is primarily desired to cultivate. An old and quaint, but very practical, book on the culture of the carp, published more than three quarters of a century ago, advises us to introduce with every 200 brood carp, 20 brood tench and 20 brood jack (pike). We can accept the author's explanation of the service of the pike, which is to check the increase (in numbers) of the carp, though we may be skeptical of the function ascribed to the tench, or "doctor fish," namely, to "act medicinally to other fish, by rubbing against them when wounded or sick."

Two chief principles which should guide us in determining the desirable combinations of fish are these. First, that the associated fish should not too severely compete with each other for food; second, that, under certain conditions at least, one of the groups of fishes should prey upon the others to such an extent as to prevent an excessive increase in numbers.

It would, beyond doubt, astonish a stock farmer to be advised to introduced a wolf into the sheep-fold; but what else should he do if he had no other practicable means of preventing his sheep from multiplying in numbers until the pasturage

could no longer support them? If seems to be true that a new pond or lake often produces within a few years fish of particularly large size, and that after a while the fish became much more numerous, but much smaller in size. This is not invariably so, of course; it depends upon the conditions of stocking, but it is easy to see how this may come about. Given at first a reasonably abundant supply of food and a small number of fish, the fish, naturally, thrive and attain rapidly to a large size. The strong healthy fish reproduce successfully and the abundant generations of young, unless soon decimated by enemies, prey so exhaustively upon the available food as even to prevent its growth in formerly normal luxuriance. The introduction, then, by natural or artificial means, of a small number of rapacious fish may lead to such a reduction in the numbers of fish, and such a consequent change in the conditions of competition as to serve the best interests of each and every species within the pond. This is why the German carp growers put pike into the carp ponds.

The control of numbers is an essential condition of success in agriculture, husbandry, or fish culture; but where fish are being reared in ponds it is usually very difficult, if at all possible, to accomplish this end by direct means. Even if the pond is so devised that it may be drained, one can not always draw the pond after each brood is hatched, and to draw the pond may also entail a loss of valuable food supply carried out with the discharge of water.

Unless it be to provide variety, there can be no good purpose served by associating species which have identical feeding habits, and which, therefore, merely compete with one another. If, however, one can group fishes of principally insectivorous with others of principally vegetational diet, it is, obviously to be expected that the pond will yield more fish per acre than if only one half of the existing supply of food could be availed of. One may often, too, wish to introduce a smaller species, which will serve as food for a larger kind that is especially desired.

While the principles of association of fish species which have been outlined may seem almost too obvious to justify discussion, it is remarkable to what an extent they are violated in fact or in intention by persons of high intelligence in all other matters. Every possible species of Salmonidæ is desired in a particular lake. An organization of men, successful in their ordinary pursuits, will want to pour into a pet pond unlimited numbers of bass, pike, pike perch and perch. If a lake frequented for sport fishing is found to contain innumerable small

crappie, the plea is for more crappie, on the fatuous assumption that "new blood" is all that is required to make the fish grow large.

The problems of appropriate associations are interesting and very important. Their solution may be attacked most directly by experiment, but also indirectly by studies of feeding habits and of associations in nature. I hope that I do not give an unduly unfavorable impression of the progress of fish cultural science, when I say that we know very little on the subject of proper association. If you wish to produce the greatest quantity of large-mouth bass per acre, what species of fish would you associate with the bass to serve as food for it—or would you leave the bass to itself and trust to cannibalism for the control of numbers? Apply the same question, if you wish, to other species; but who will now supply the answers based not upon opinion, but upon the sure footing of experimental determination?

In concluding, it seems to me that an apology may be due to the readers of THE SCIENTIFIC MONTHLY for presenting a paper which contains so little that is original, and which makes no pretense of adding to the sum total of knowledge. The purpose has been merely to indicate, from one incomplete point of view, a common meeting ground for the fish culturist and the ecologist, the zoologist and the botanist. If this shall lead, in any way, to more frequent meetings upon that ground, the effort of the writer and the time of the reader will not have been wasted.

THE ENGINEERING PROFESSION FIFTY YEARS HENCE. III

By DR. J. A. L. WADDELL

PROMOTION OF PROJECTS

Americans for two centuries have been notorious as promoters of projects. For this habit they have often been adversely criticized; but it should not be forgotten that, were it not for the enterprise, zeal, and courage of such men, our country would not be standing to-day as the acknowledged leader of the world. It is true that promotions used often to be carried to extremes, and that wild-cat schemes were only too common. The almost irrepressible enthusiasm of Americans needed a curb, and it certainly got it soon after the academy appointed a standing committee to pass upon all projects submitted to it involving the expenditure of more than a quarter of a million dollars. Bankers soon dropped into the habit of refusing to consider any large project that did not have the endorsement of the academy. The investigation of the soundness of any project is not done directly by the committee but by an engineer, or a firm of engineers, chosen by the said committee and paid a standard fee by the promoter. No real hardship for the latter is involved by this arrangement, because he is not actually compelled to come to the academy for an endorsement, although, truth to tell, the number of promoters is far smaller to-day than it used to be formerly. On the other hand, a far greater proportion of the schemes submitted to capitalists is materialized.

WORKING ABROAD

Until the beginning of the third decade of the century, American financiers and business men were so interested in the development of our own country that they neglected the fine opportunities which constantly presented themselves for securing work abroad, especially in Latin America, although there was no dearth of American engineers who were eager to go to such countries in the service of any sound corporation. Some of them were willing to do more, for, having the "roving spirit" in their blood, they went as soldiers of fortune to Mexico, Cuba, and many of the South American republics. A

few of them made good, but the large majority sooner or later came to grief for one cause or another. It was, as once before stated, the Great War that opened the eyes of Americans to the business opportunities in the countries to the south. At first the failure of our young men to understand Spanish militated greatly against progress in business with the Latin Americans; but a wave of enthusiasm for the study of that language suddenly overtook the country, and soon thereafter a large number of young American men and women possessed a good working knowledge of *la lengua castellana;* and their services were in immediate demand at good salaries.

There existed up to the end of the second decade a condition which acted adversely and seriously against the establishment on a large scale of business relations with foreign countries, viz., the apathy of the American government in protecting the rights of its citizens outside the boundaries of the United States. When Mr. William Jennings Bryan was Secretary of State, he made it plain to our soldiers of fortune and to our financial men that if they invested their money abroad it would be at their own risk, and that they need not look to the United States government for protection, in case of being defrauded of their foreign holdings by any illegal or piratical act of another nation. Such a pusillanimous doctrine was a disgrace to our country! Fortunately, the war taught the Administration the fallacy of it, and brought on a change of heart, with the result that now there is no nation in the world whose citizens are as well treated in foreign countries as are ours. It took years and much effort to accomplish this desideratum; but the result is worth incomparably more than all of the labor involved.

In the development of business relations with all foreign countries our academy has played a leading part, in that through its honorary members, who are always chosen from the most prominent and active engineers abroad, it receives annually therefrom reports concerning the progress of all kinds of engineering works during the past year. Besides, these honorary members have often interested themselves in promoting closer business relations between their countrymen and ours.

Publicity Movements

The publicity movement started by the Cleveland Engineering Society a little over fifty years ago, with the double object of bringing local engineers into touch with their fellow townsmen, and of making the latter conversant in an interesting way with the most important of the current feats of engineering,

was gradually taken up by the local technical societies of other cities, until in time our profession became well and favorably known to the general public throughout the country. This movement was and still is fostered and encouraged by our academy through its specially friendly relations with the engineers' clubs and local technical societies which are now to be found in all American cities of any size.

Public Recognition

As the education of engineers became broader, they took more interest than formerly in local, state, and national politics; and because of their superior mental attainments, people soon began to select them as their representatives, at first as mayors and city managers, then as state legislators and governors, and then as U. S. congressmen and senators. Finally, in 1932, a civil engineer was elected president of the United States, thus making our country follow the example set by Cuba in 1912, when it elected General Menocal, a civil engineer of high standing, to the presidency of that republic. Since 1932 two other engineers have occupied the presidential chair at the White House.

Public recognition is truly the main object of engineering endeavor, because engineers more than any other class of people place honor and glory above the "almighty dollar," although it can not be denied that the accumulation of a reasonable amount of wealth is a proper ambition for any technical man.

This brings to a close my observations concerning the main causes of the wonderful advancement of the engineering profession during the last half-century; and now I shall proceed to indicate the most striking improvements which have been effected during that period in the various lines of engineering activity, taking them up in alphabetical order so as to avoid all possibility of criticism for alleged partiality.

Aeronautics

While the flying machine was made a *fait accompli* only in 1907, its perfection into a serviceable means of transportation was hastened by the Great War and by the silent preparation therefor on the part of some of the contestants. As a fighting machine it then reached the acme of perfection, because there has been no real war subsequently; but as a means of transportation for the business of peace it has since been wonderfully improved, and its carrying capacity has been augmented fully twenty-fold. There are now regular lines of passenger airships flying between the principal cities of the North American con-

tinent, and a considerable amount of first-class mail and a smaller amount of light express matter travel in the same manner; but it has not proved economical to transport freight through the air.

So great is the air-travel that it has been found necessary to pass stringent laws confining planes going to and from certain places and in certain directions to limited spaces, in order to avoid collisions. However, it has very seldom been found feasible to punish offenders for the infraction of these laws, because, if they escape collision, it is difficult to establish proof of the offense, while if they do not, it is generally unnecessary to penalize them.

Nearly fifty years ago the first flight to Europe was accomplished; and since then some desultory flying across the ocean has been practisced, but nothing of the kind on a commercial scale has yet been effected, in spite of repeated trials. Many of the hitherto inaccessible places of the world, such as mountain-tops and the lands of perpetual snow and ice, have been reached by the airplane; but such trips are fraught with so much peril that they have not become popular. Practically all of them have been made in the interests of science and exploration, only a few of them having proved remunerative through the discovery of deposits of certain rare minerals of value in the arts. The development and perfecting of the helicopter have enabled airplanes to alight with almost no shock in small spaces and to rise vertically from the ground. All the high mountains of the world have been sailed over by the airplane, consequently there is now no place on the earth which has not been visited by man. One of the most useful fields of the aeroplane is in making reconnaissances and preliminary surveys for railroads, continuous photographs of the country being taken, and the mapping thereof being done automatically—of course, in a rather crude manner, but with sufficient accuracy for exploratory work.

Agricultural Engineering

Agriculture as practised in America during the nineteenth century was exceedingly extravagant and crude. Very little scientific study was given to the subject until the state universities about 1900 began methodically to teach agriculture. The universities of the middle west were the first institutions to take hold of the matter in real earnest; and it was an acknowledged fact that the University of Wisconsin doubled the agricultural product of the state in a very few years simply by teaching its farmers the rudiments of scientific farming.

The shortage of food for the entire world during the Great War brought home to the American people the realization of the necessity for more thorough and economic methods of cultivating their soil. About all that could be done during the struggle was to increase the acreage of the crops and work longer hours, with the result that a material enlargement of the output was effected. Some attention, too, was then given to richer fertilization, but it was not until after peace had been declared that a systematic study was made of the problem of really multiplying materially the outputs of the various products of the soil in the different parts of the country. Commissions were sent to China, Japan, India, Holland, Belgium, and some other countries to study intensive farming; the best rotation of crops for the different soils was determined; economic fertilization was thoroughly investigated; the destruction of insect and animal pests was studied and put into practise; the utilization of all farm produce was established so firmly that the waste of anything at all usable soon came to be considered almost a crime; the breeding of domestic animals was reduced to a science; the employment of power instead of human labor, wherever possible, became widespread; the proper housing and care of machinery and tools was made compulsory by law; effective protection against fire and flood was instituted; all the really necessary conveniences and comforts of city life were brought to the farmers' houses; the roads were so improved as to reduce to a minimum the cost of hauling produce to market; and the life of the farmer and his family was made so attractive as to call to the soil the overplus of population which used to render our great cities so unhealthful and make urban life such a burden to the poor.

The production on a large scale of nitrates from the atmosphere, now a government monopoly, has done much to prevent the exhaustion of the soil. The taking over of this industry by the government was a natural sequence of its control of the manufacture and distribution of power, concerning which I have previously spoken at length. All excess power, or that which is not required for other purposes, is employed for nitrate production; and in seasons of flood the hydro-electric-power plants manufacture and store immense supplies of that material.

Applied Chemistry

As indicated previously, the Great War started such a boom of activity in chemical engineering as to make America subsequently independent of Europe not only for all the necessities

but also for many of the luxuries of modern life, as well as for war supplies of every description, in case such should ever again be needed. New departments in our universities and technical schools for chemical engineering soon sprang into existence; and that branch of the profession quickly became one of the most popular and lucrative of them all, and has so continued to be ever since. In the economic disposal of sewage and garbage, chemical engineering has played a leading part.

BRIDGES

Fifty years ago bridge building had truly been reduced to a science; for it had been more thoroughly investigated and written up than any other branch of engineering. For that reason there have not been made in the last half-century as many improvements in this specialty as there have been in most of the others. In 1917, one of the leading bridge engineers of those days stated that the near future would mark the end of long-span bridge-construction, because the increasing scarcity of structural materials and the consequent rise in their price would render their cost prohibitive. As a prophet, he proved an utter failure, because scores of long-span bridges have since been constructed, the longest span being about three thousand feet in the case of the North River Highway Bridge at New York City. His alarm over the growing dearth of structural materials proved to be groundless, because soon afterwards enormous deposits of both fuel and iron were discovered. They were not developed, however, for some years, because the old sources of supply were sufficient, and because expensive lines of transportation were required to reach many of the new deposits.

Time has shown that the demand for a large bridge at an important crossing increases with the development of the adjacent metropolitan communities. Not only is there a continual growth in the keen necessity for lines of transportation over the water, but there is also an accompanying and more than proportionate growth in the wealth of the communities affected. With such increasing wealth there is bound to come a time when the demand for a bridge will far outweigh the obstacle of expense. In other words, the capitalized economic value of the project will ultimately increase to a point where it will more than balance the cost of construction.

The main reason for the existence to-day of so many long-span bridges is the fact that we have at our disposal for their building a truly high alloy of steel. That such is the case is due

to the persistent efforts of my grandfather, extended over a period of two decades, in his search for an ideal alloy for long-span bridge building. His extensive experiments in the early twenties, using Mayarí steel as a basis, resulted in the obtaining of alloys having the following elastic limits:

For plate-and-shape steel, to be sub-punched and reamed, 65,000 pounds per square inch; for plate-and-shape steel, to be drilled solid, 75,000 pounds per square inch; and for eye-bar steel, heat-treated, 90,000 pounds per square inch. No material improvement in alloy bridge-steel has since been made, excepting only that it has been found practicable to manufacture heat-treated eye-bars having an elastic limit of 100,000 pounds per square inch.

The use of reinforced concrete for bridges has increased immensely in the past half-century. It is very seldom to-day that any span under 250 feet is built of steel; and reinforced-concrete arches of 350 feet span are not uncommon. A few longer ones have been built, one as long as 460 feet, but they are uneconomic on account of the great expense of erection and the numerous difficulties encountered in keeping the arch rings to proper elevation during construction.

In pier foundations no important advance has been made since the building of the great Mississippi River Bridge at New Orleans, where the piers were sunk 225 feet below low water, and had their bases enlarged by the injection of grouting. The pneumatic process of pier sinking has been somewhat improved, so that it is now comparatively safe for the workmen to operate under a head of 125 feet of water; and in a few cases pneumatic piers have been put down several feet deeper than this.

For certain new railroad lines with the widened gauge, the actual live loads have been increased to Class 85, which means axle-loadings of 85,000 pounds and carloads of 8,500 pounds per lineal foot; but for the standard-gauge railroads the old maximum of Class 70 still suffices, for the reason that it is as large a loading as the old-fashioned type of track will support.

In highway bridges there are no more wooden floors, even in country districts, because the auto-truck loads that are employed in all parts of North America are so great that it is unsafe to run them over any plank floor supported on timber joists. That type of floor system received vigorous adverse comment in the technical press in 1918, but it took a full decade to educate the public to an appreciation of its unfitness for carrying modern highway live loads.

Canals

In no line of engineering in the United States has greater progress been made during the past fifty years than in that of canal building. Immediately after the conclusion of the Great War, work was started on the Bowen Canal, joining Lakes Erie and Ontario and running behind the city of Buffalo, so as to reverse the flow of all the streams and main sewers in that city. The object of the canal is three-fold, viz.: It is a ship canal that accommodates the largest-sized vessels on the Great Lakes; it withdraws the sewage of Buffalo and the neighboring towns from the Niagara River and thus permits the water of the latter to be safely utilized for drinking purposes; and it develops some 750,000 horse-power. Its two lift-locks, each consisting of a pair of balanced steel tanks, some 660 feet long, 70 feet wide in the clear, and 35 feet deep, to contain 30 feet of water, in one the rise being 208 feet and in the other 104 feet, were an innovation in canal building; and nothing like them in magnitude has since been constructed.

Following the completion of this immense work, a series of canals and deepened rivers was begun so as to make it practicable not only for all lake vessels to reach the ocean, but also for a large proportion of ocean-going vessels to pass to the Great Lakes and discharge and take on cargoes at all of the large cities situated thereon.

Simultaneously with these there was constructed by the federal government the Inter-Coastal Canal, extending from the city of Boston to the mouth of the Rio Grande, and continued from there by the Mexican government as far as Vera Cruz. Ultimately it may be extended still farther.

Early in the forties our government undertook the construction of another interoceanic canal, adopting therefor the old Nicaragua route. It required nearly ten years to complete the work of construction.

Again, it was found economical to build on an enlarged scale many barge canals in various parts of the country, so as to lessen the cost of hauling produce, including the Great North-and-South Canal, which extends from the Canadian border to the Gulf of Mexico.

Heating

The development of central heating-plants in cities and large towns which took place during the third decade of the century solved one of the most difficult problems of housing in congested urban areas. In country districts and small towns, where such plants would not be economical, heating by elec-

tricity is now usual, in spite of the fact that it is apparently more expensive than the burning of fuel. This is because of the large saving in labor involved by employing electricity—and nowadays man-power is much more highly appreciated and conserved than it was half a century ago.

Hydraulics

Important advances have been made in the science of hydraulic engineering during the fifty years past. Late in 1917 one of America's most prominent hydraulic engineers in a private letter wrote as follows:

> The profession is somewhat handicapped by holding conventional views of water instead of a thorough knowledge of the internal workings and nature thereof. . . .
>
> I have found that the hydraulics of the rivers themselves are very vaguely understood. The quantity of water flowing, the water surface elevation at many points corresponding to these volumes, and the length of time in which a change of stage is transmitted over forty or fifty miles of river concerned, are all rather vaguely comprehended; and in many cases text-book formulas instead of observations are used. I find an astounding amount of adventurous design in dams, evidenced by many failures. One of the causes of failure is the lack of understanding concerning the matter of the standing wave, in which water changes from a dynamic condition to one of more nearly static equilibrium. How to build a dam upon a glacial-drift foundation and utilize the full head available, thus conserving the water power, has not yet been clearly worked out.
>
> Perhaps one of the chief faults in such cases is the lack of experimental data, preceding design and construction. In other words, we operate on the patient before we diagnose the case thoroughly. As the years go by we shall emphasize preliminary diagnosis in all engineering matters.

Some five years after the above was written, through the influence of our academy, the American government was persuaded into appointing a well-paid board of three of the country's most prominent hydraulic engineers (including, by the way, the writer of the letter just quoted) to study with a large force of assistants a number of hitherto unsolved questions in hydraulics. The work of that committee extended over a period of seven years; and the results of its investigations are of exceeding value. All the great hydraulic works of the world undertaken since the publication of its report have been based on its findings, and the saving of money resulting runs into the hundreds of millions of dollars.

Irrigation

During the early portion of the century, irrigation projects in the United States fell into disrepute, because many of them

had proved financial failures. This was due to the promoters having either dispensed with engineers' services altogether or else retained cheap ones who did not possess the necessary ability or experience. On that account it was almost impracticable fifty years ago to find an American banker who would finance an irrigation enterprise, no matter how promising the prospectus might show it to be. But as the country became more and more settled, there arose a demand for irrigable lands that could not be withstood, and irrigation once more came into its own. To-day there is left in our country comparatively little unwatered land that is capable of being irrigated at any reasonable expense. Our irrigated lands are the largest producing, the most reliable, and the highest priced of all the cultivated lands of the country, not excepting even the reclaimed lands of the Mississippi River delta.

Allied to irrigation is the watering of crops by the artificial precipitation of moisture. Early in the century certain credulous persons (as well as a few designing ones) made themselves ridiculous by vainly trying to cause rainfall in the arid districts of Kansas through the firing of cannon and the explosion of bombs. This fiasco made scientific men rather chary of even mentioning the subject of artificial rainfall; nevertheless Chiera Maclen Whask, C.E., in the early twenties proposed to some of his friends that they try to condense the fogs which blow from the Pacific Ocean over the tablelands of Southern California by spraying from above them liquid air carried on aeroplanes. Some experiments made thus by private subscription showed the scheme to be feasible; and it was then undertaken on a large scale by the Department of Public Works and proved to be a commercial success. The method has been followed in several districts along the Pacific coast of South America.

Levees

For about a century the building of levees in the Mississippi River delta was done piecemeal and in a haphazard and desultory manner, with the result that the said levees were being continually broken or overflowed, to the great detriment of the bottomlands for a considerable distance both above and below. The levees were lacking in both height and strength; and they were built in short lengths by different communities. Of course, under such conditions they were without system; and the protected (?) lands were annually in danger of being flooded. This prevented their proper settlement and development.

In the early twenties there was appointed a commission of engineers, first, to report upon the control of the Mississippi River and the reclamation and development of the adjoining lands, including the entire delta, and, second, to attend to the work of the said reclamation and development. It took a dozen years to complete the work, which was all done at the joint expense of the United States government and of the several states wherein the reclaimed lands were located. The products from these reclaimed lands are of a greatness and value staggering to the mind and almost incomprehensible. The soil is exceedingly rich; and most of it bears two crops per annum—in some places three. These lands truly form the garden-spot of the world, comparing in yielding capacity per acre quite favorably with the best of the irrigated lands of the West.

Lighting

Owing to the uniform distribution of power throughout the land, the problem of lighting has become a very simple one, and the farmer as well as the city-dweller now has all the light he needs for every purpose at a reasonable price. Being under government control, all lighting apparatus is kept in good repair and at a minimum of expense.

Materials of Engineering

Very few new materials for engineering work have come into use during the past half-century, but the old ones have been much improved, their scope has been greatly enlarged, and the cost of their production has been materially reduced. Numerous alloys of the metals have been manufactured and employed in the arts upon a commercial basis, including the before-mentioned high-alloy of steel for long-span bridges; the manufacture of hydraulic cement has been cheapened; and the use of timber has been reduced to a minimum. The heat-treatment of steel has increased its strength from two to three fold. Wrought iron has come back into use for many things in the manufacture of which it is superior to steel—for instance, tinned plate, metal employed near salt water, and cylinders for bridge-piers. The Bruntwasler process, developed after long delay in the early twenties, permitted the making of wrought iron directly from the ore, and thus kept the price down to a reasonable figure.

Mining

In this line of engineering the improvements have not been so marked as in most of the other lines. The dwindling supply

of gold has forced the adoption of more economic methods of extraction; and the increased demand for iron products has necessitated a cheapening of the mining of the ore as well as of the reduction of the metal therefrom. Most of the improvements in mining consist in the development of economic methods, and especially by working upon a large scale. The drainage of mines has received much attention; and it has been found practicable to operate deeper workings than formerly.

Power

Concerning this matter I have spoken at length before, and I, therefore, have not much more to say upon the subject, except to remark that a large elimination of physical labor has been effected by means of the development of machinery in many ways formerly thought impossible or uneconomical. There is an old saying to the effect that anything which can be manufactured by hand can be manufactured also by machinery; and it seems to have been nearly, if not quite, true.

Railroading

In railroading some fundamental improvements have been made in the last half-century, though not many in the standard-gauge system, which was used exclusively till about 1929, when the first wide-gauge trunk-line was built from Pittsburgh to the Great Lakes so as to carry long trains of ore cars weighing when loaded as much as 8,000 pounds per lineal foot. The gauge was made six and a half feet, and the rails were laid upon a concrete base, but not until after the embankments had come to a final settlement. Since then a number of other railroads have been built in that manner, but they are all used exclusively for carrying heavy freight between terminal points, and not for the ordinary distribution of light freight, which can be handled more economically by standard-gauge lines, especially since they have all been electrified. The last of the steam locomotives went out of commission some twelve years ago. They were found to be less economical in operation than electric locomotives, besides being exceedingly offensive to the traveling public because of their smoke. The building of very long tunnels, in order to reduce the heavy grades that used to exist on our transcontinental roads, rendered the employment of steam locomotives really dangerous to human life. The change in power began by the electrification of lines through such tunnels, and gradually extended so as to cover the rest of the line on which the tunnels were located. Finally, the electrically

operated lines proved to be so satisfactory that all lines were eventually electrified.

Considerable expensive railroad work has been done of late years by building belt lines around all large cities, not only to connect the various systems passing through them, but also to divert through-freight away from congested traffic-centers.

Another innovation in railroading was the adoption of the monorail system of transportation, evolved by Charles Whiting Baker and introduced by him in the early twenties, after many trials and tribulations. It is employed generally as a feeder to other railroads and to take the place of the electric railway in those localities where a more expensive type of construction is not warranted. At first the Baker system was operated solely by gasoline engines, but since it was proved to be a success it has sometimes been run by electricity.

Attention has been paid of late years to reducing the noise of operating railroads, and the attempt has proved quite successful.

Another important improvement in railroading has been the installment of automatic block signals, which now work to perfection.

The immense increase in the number of automobiles and the high speed at which they are driven have rendered imperative the separation of grade of streets and roads from railroad tracks, except in a few localities where the automobile traffic is light. It required federal control to establish this innovation; and in securing it the American Academy of Engineers took the leading part. The problem was essentially a financial one; and it was settled by dividing the expense of grade separation upon an equitable basis (which varied for different localities and different conditions) between the railroads, the federal government, and the municipal or state government.

In railroading, as in all other lines of technical activity, the substitution of machine labor for hand labor has effected great improvements—for instance, tie-tamping machines, ditching machines, rail-loaders and unloaders, and track-laying machines.

The old, slow process of surveying railway lines, taking topography and platting to scale on maps by using large forces of men has been very much simplified. Instruments of precision have been designed which traverse the sections of the country under investigation and accurately record on maps and profiles by fixed scales the same data that used to be obtained

by employing several field parties. As before mentioned, the aeroplane has been utilized to much advantage in railroad surveying.

The long-discussed question of government operation of railroads was settled by experience obtained during the Great War. It was finally decided thereafter that it would be better to continue to let the railroads operate as previously—but with certain restrictions, as well as certain liberties formerly denied them, rather than to leave them absolutely under government control. The restrictions of the Interstate Commerce Commission had proved to be so drastic and severe that the gross earnings decreased and the operating expenses increased to such an extent that the result was an annual deficit instead of an annual profit. Under continued conditions of this kind, the public refused to invest its savings in railroad securities; and, in consequence, railroad construction throughout the United States came to a standstill. Nor did the roads earn enough money even for up-keep of line and rolling stock; consequently the condition of the systems had deteriorated, wrecks had become common, and more or less general demoralization had ensued up to the end of 1917, when the government assumed control for the period of the war.

Pooling had been prohibited and treated as a crime; but the government itself soon learned that that method of operation was the only sane and economical one possible. Eventually, private ownership with government supervision, cooperation, and support was decided upon as the logical solution of the knotty problem. Experience has proved that it was a wise decision; for now when private investors refuse to lend their money for necessary improvements, the government lends what is needed; a legitimate pooling of interests of competing roads has been adopted; and the officials responsible for results have the opportunity of selecting those extensions which will be most beneficial to the wholesome growth and development of the country, and are in a position to prevent ill-advised duplication and multiplication of competing facilities, such as in times past placed an insupportable burden upon certain railroads and the communities that they served.

Reclamation

I have already referred at length to the reclamation of lands along the Mississippi River. Other minor rivers have been treated in the same manner, swamps have been drained, and sandy places have been covered with fertile soil. The

drainage of the immense swamps of Florida and of some of the other Gulf States has thrown open to settlement agricultural lands of untold value and productiveness.

The most elaborate and expensive reclamation project ever undertaken, or even contemplated, is that of New York Bay and the adjacent waters. It was conceived and advocated over fifty years ago by T. Kennard Thomson, a consulting engineer of New York City. After much discouragement, he finally succeeded in getting work started on his immense enterprise; but it has required fully four decades of hard work and untold millions of money to complete less than one half of the original scheme, notwithstanding the fact that, from the commercial standpoint, it has proved a success.

Reinforced-Concrete Construction

The use of reinforced concrete of late years has become far more general than was anticipated fifty years ago; for to-day it seems that almost any construction, large or small, excepting long-span bridges, can be built of that material. During war times, the reinforced-concrete vessel was perfected; and since then that material has usurped the place of steel, stone, brick, and timber in constructions of all kinds. When scientifically and honestly manufactured and used, it is a thoroughly reliable material; and the cost of its maintenance and repair, as compared with other types of construction, is truly a minimum.

River Improvement

In addition to the leveeing of the lower Mississippi River and the reclamation of the adjoining lands before mentioned, a scientific study of the problem of how best to improve the other navigable rivers of the United States was made at the expense of the government and under the management of our academy. A commission of seven expert engineers in various lines was appointed, with instructions to study certain of our great rivers and report upon how best to improve them so as to care for navigation, shore protection, water-supply, drainage, irrigation, and power. All these desiderata were to be duly weighed and evaluated, so as to determine in every case whether each item should be considered or ignored; and, if considered, to what extent. After the report upon each river was completed, the government (through our academy) decided what improvements were advisable for the immediate future, how they should be effected, what works could properly be relegated to the distant future, and what provision should be made for their ultimate

accomplishment. Then the improvement was regularly undertaken by the Department of Public Works, which body at times utilized its privilege of calling upon the academy for advice and counsel.

Another river improvement (of a temporary nature, however) that has been undertaken by the federal government of late years is the keeping open during the winter months, by means of ice-breakers, certain navigable waters, including among others the Mississippi up to St. Louis, the Hudson up to Albany, and the Ohio up to Pittsburgh.

The river improvements of our country are by no means completed—in fact one might say that they are merely started; for much yet remains to be done to help the regulation of the flow by building storage reservoirs near the headwaters and thus incidentally irrigating lands and developing power.

Roads

Fifty years ago the extravagance involved in the then-prevalent methods of road construction was simply a crime! From one end of the country to the other the people's money was squandered by incompetent, and often dishonest, county or township supervisors. Many of these men used to claim that they knew how to build roads as well as any engineer, consequently road-construction was hardly considered by our profession as coming within its realm of activity. A reaction began to set in about the end of the second decade, and a certain amount of roadwork was undertaken by some of the state governments; but it took many years to establish road-building upon its present satisfactory basis. To-day the great highways of the country are under federal control, and are handled by the Department of Public Works through its "Bureau of Roads"; and all other road-building comes under the jurisdiction of the various states, each state government having a special bureau therefor. As a result of this arrangement, our common roads are the most perfect of any in the world; and it is universally conceded that they pay for their first cost and upkeep many times over by reason of the fine facilities which they afford the farming community for delivering produce to the main arteries of transportation. Pleasure-travel by automobile, in consequence of our good roads, has become the most popular pastime of the nation; and the reaction therefrom upon the people through enlarging their horizon of acquaintance has been strikingly valuable.

Sanitary Engineering

When one looks back upon the wasteful methods of sewage disposal which governed half a century ago, he can not but wonder how intelligent people—especially engineers—could countenance the discharge of unpurified sewage and waste products of manufactories into the streams and lakes, thus ruining them for water-supply and destroying the fish, besides wasting millions of tons of fertilizer so sadly needed by the farmers.

To-day it is not permitted to turn unpurified sewage into any water-course or lake; and the sources of our drinking water are guarded against pollution by the strictest kind of supervision. The result is that the people have pure water not only to drink but also to utilize in the arts; our lakes, rivers, and streams teem with fine fish, the supply of which is kept up by federal control; and the exhaustion of the country's soil, which was increasing at such an alarming rate a few decades ago, has ceased. Moreover, these are not the only important benefits secured through the adoption of common-sense methods of sewage disposal; because its effect on general health by the reduction almost to zero of certain diseases, which in times past were often veritable scourges, has proved to be a god-send to the community. I speak truly when I state that the consummation of this great economic reform is due primarily to the efforts of our academy, which brought a number of other technical societies, economic organizations and municipal governments into line, and thus induced Congress to pass and put into effect the necessary laws.

Steamships

The improvements in ship-building of the last fifty years have been simply marvellous. Not only are the vessels far larger than they were formerly, but also they are equipped with every modern comfort and convenience for passengers and every facility for the economic handling of freight. Moreover, they are now made almost unsinkable; and the lanes of travel are so strictly followed that collisions of vessels at sea are almost unknown. The signaling between vessels and with the shore has been perfected; and various kinds of apparatus, working automatically, indicate the proximity and direction of other craft, icebergs and the land. No great increase in speed has been achieved, because the economic velocity of travel had already been attained half a century ago. It is true that we now can develop somewhat greater speeds, but it is not economical

to do so, except in special cases for the purpose of meeting unusual conditions.

Steel Buildings

In steel-building construction no fundamental advance has been achieved in the last half-century. It is true that we have in New York City an eighty-story building, but it has proved to be a white elephant for its owners. It has been found advisable in tall-building construction to study very carefully in each case all the conditions from the economic viewpoint, so as to determine what will be the best height to adopt when everything is given due consideration.

The Telegraph

Since the discovery of wireless telegraphy some sixty years ago, no fundamental improvement has been made in this branch of technics, unless it be the "teletypograph." By this apparatus there can be produced at any place in the United States or Canada, and also simultaneously at a great number of places, the contents of a typewritten page, the time required for transmission and reproduction being about one second. The message to be sent is first typed with a special ribbon upon a special kind of paper, and then this is run through a pair of rolls similar to those of the old-fashioned clothes-wringer. The distant reproductions are made on similar paper by means of a special ink.

The Telephone

The improvements in telephony of the past fifty years have been mainly in detail, excepting only that the wireless telephone has been perfected. It has not, however, put out of commission the ordinary telephone system in which wires are employed.

It has been found practicable to utilize a wire simultaneously for half a dozen messages without involving any interference; and the recording by phonograph of long-distance messages sent by wire is now not merely practicable, but is truly a paying business-venture. Some bold technical dreamers have lately been talking of recording in a similar manner telephone messages sent by wireless, but thus far nothing has really been accomplished through their experiments.

Tunneling

In tunneling no great strides have been made in the fifty years past. Much longer tunnels have been constructed than were formerly built; but in subaqueous tunnel-work it has not

been found practicable to go much lower than one hundred feet below water, although in a few cases that depth has been exceeded by ten or twelve feet. We still have to depend upon compressed air to keep back the water. The freezing process did not prove to be commercially practicable for tunnels, although it has solved some difficult problems in the sinking of deep shafts. Important improvements have been made in the methods of tunnel-construction, and the unit prices of excavation therefor have been brought to very low figures.

WATER SUPPLY

No startling innovations in water supply have been made for many years, although a number of valuable improvements have been effected. In addition to the control of the pollution of watersheds previously mentioned, I might call attention to the use of Mayarí steel for pipes, which has increased their strength fully fifty per cent. and their cost in place only from twenty to twenty-five per cent. for the same weight of metal; to the greatly increased efficiency of pumping equipment; to the wonderfully dependable and durable coating for steel and iron, called "Anticorro"; and to the efficient and absolutely unobjectionable modern methods of purifying drinking water.

CONCLUSION

In drawing this rather lengthy address to a close, I should like to speculate as to what important improvements in engineering will be evolved in the next fifty years, so as, in a measure, to anticipate the retiring address of my distant successor in office when our academy celebrates the one hundredth anniversary of its establishment; but any attempt to do so would certainly prove futile. I must confess that I can not even prognosticate as to whether the progress in engineering during the next half-century will exceed or fall behind that of the one just ended; but this much I can very safely foretell: Whatever the said progress may be, a large proportion of it will be due to the initiative of our well-beloved society, The American Academy of Engineers.

RESEARCH AND THE INDUSTRIES

By DR. P. G. NUTTING

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ACCORDING to the older view, an industry is composed of two elements—capital and labor. This is true to-day of the smaller and less technical manufacturing concerns. Capital supplies plant and equipment and covers the lag between expense for material and receipts from sales. Labor prepares and fabricates material according to accepted methods, keeps the plant in order and suggests improvements. The manager may be in the ranks of either capital or labor.

But a large, progressive, modern industry is operated on quite a different plan. *Capital* is represented only by a group of bankers in the dim background. The thousands of technical operatives of all grades representing *labor* follow routine instructions or work to blue prints. The vital part of the organization is the *technical expert*, everywhere directing the various departments, divisions and sections, designing new products, developing new ideas, eliminating troubles, testing raw materials and finished products. Without him the industry would go on the rocks at the first serious works trouble and even in the absence of such would be rapidly outdistanced by progressive rivals. The technical expert may or may not be financially interested in his company—it is immaterial. He is a professional solver of problems and applier of fundamental principles in quite the same sense as a physician or lawyer. He has his own capital invested in his own brain by reason of the expense for his special education and training. He represents a class quite distinct from either capital or labor, much as would a man with a special, unique machine of his own, hired for a special job.

The training of the industrial expert may be in any of a wide variety of different *fields*, ranging from statistics to science. A large progressive concern usually has at least the following separate departments: Accounts, Education, Engineering (including Research), Executive, Export, Legal (including Patent), Mailing, Publicity, Sales, Service, Treasury, Traffic and Works. In each of these (with its divisions and sections) are experts of all *grades*, smoothing out troubles, checking the

work of less skilled labor, dealing with outsiders, solving general problems and finally anticipating requirements in the nature of fundamental principles by extended investigations of the principles underlying general problems. Within each grade of each field of expert knowledge individual characteristics come into play and the work may properly be made to fit the man, or rather, the man allowed to cut out his own field of endeavor according to his taste and training.

In relation to *organized knowledge*, the nation as a whole is concerned with its dissemination through education, its increase through research and its application to special problems of all kinds in all fields. The promotion of each is the self-evident course toward the ultimate goal of all our problems solved by experts, the elimination of misguided effort and the rule of common sense everywhere. The large industrial unit stands in precisely this relation to organized knowledge, but chiefly only in selected fields, and in these is concerned not so much with education as with research and the application of the results of research through engineering.

Industrial research is one of the three great classes by which the great bulk of the increase in organized knowledge is made. The investigation of fundamental laws and phenomena is naturally and probably always will be associated with our universities and our greatest teachers and leaders. We look to *university* research to advance our knowledge of the structure of the atom, gravitation, valence, relativity and similar phenomena. Problems in such fields as astronomy and astrophysics, geophysics and terrestrial magnetism are properly the charge of either university or of privately endowed research laboratories. It is the field of *national* research, directly endowed and fostered by national and state governments, to solve problems of general practical interest such as are related to public health, food, forestry, soil physics, road building, animal hubandry, education, the maintenance of standards and the development and conservation of public resources. Such problems fall outside the bounds of both industrial and university research. The existence of a number of privately owned and of cooperative research corporations in a flourishing condition attest the commercial value of research by technically trained experts.

There exists a widespread but fallacious notion that industrial research deals chiefly with cures for works troubles. As a matter of fact that represents but one extreme, the other extreme being the purest of "pure" research and the average

being nearly or quite as fundamental as the average university research in physics or chemistry. Industrial research is usually directed along lines of more or less direct interest to the company, but almost invariably leads to results of general or theoretical interest. On the other hand, hardly any research is so "pure" but that it will yield some results of commercial value. In the investigation of difficult industrial problems, it is usually found necessary to continually dig deeper and deeper until the very foundations of the science are reached. Industrial research can not be distinguished from "pure" research, except that in one case it is the scientific results that are the by-products, while, in the other it is the results of commercial interest which are regarded as incidental. In a typical large industrial research laboratory the main line product is a series of reports from the laboratory to the chief of the division; the by-products are scientific papers and patents. It would be difficult to name a piece of research which would not be likely to yield all three classes of results: scientific, technical and patentable.

But research is exceedingly expensive and the results are very uncertain. Why is it that manufacturing concerns are so ready to start and maintain research laboratories, particularly since so much of physics and chemistry has already been worked out? In any industrial plant the need of research work and research men is usually first felt in the need of *improvements in products* and of *utilizing by-products.* The factory superintendent and his experienced foremen have been able to handle the ordinary run of works troubles and make minor improvements. But they find themselves handicapped by the lack of deeper insight into materials and their behavior. Why does one lot of material give good results and the next fail utterly even though chemical analysis reveals no difference? What is the cause of blow holes in castings and how may they be eliminated? The elimination of obscure works troubles calls for expert technical advice and no manufacturing concern can go very far without feeling the need of it. As a general rule the expert with just the required knowledge can not be found or is employed by a rival concern. If the problem is turned over to a private or cooperative laboratory, a solution of their problem may be attained, but they have no further control over the investigator, valuable by-products of the research are wasted and a crop of succeeding related problems must go unharvested. The results are far less satisfactory than when the concern has its own laboratory.

But probably the most urgent *raison d'être* for industrial research laboratories is the constant danger of being out-distanced by competitors. Of two otherwise equal concerns, one of which has plenty of skilled scientific and technical assistance and the other has not, the former is sure to forge steadily ahead of its unprogressive competitor by making more far-reaching improvements and by utilizing waste products. Even bakeries and laundries find research pays in cutting down losses and making improvements in processes. The balance is a delicate one, since the results are cumulative.

The notion that physics or chemistry is "all worked out" can hardly exist except in the mind of the student. As a typical concrete example of industrial research work let us consider the problem of condenser dielectrics. The student has learned the definition of dielectric constant and how to measure it. He knows his electromagnetic theory and the relation between refractive index and dielectric constant. He knows that constant to be an important one in organic chemistry and that it varies with frequency. But the industrial concern wishes to know what is the best dielectric to use in a given kind of condenser. That dielectric must have a high dielectric constant with high dielectric strength and low watt loss. It must be insoluble in certain oils, but soluble in certain solvents. It must be fusible, but must have high melting point and must be stable. Finally, it must be reasonable in price. The organic chemist has a rich field of fats, oils and waxes to cover; acids and esters, halogenated hydrocarbons, ketones and the like to prepare and try out. The physicist must devise new and more precise methods of measuring dielectric constant and of separating the leakage current from the displacement current in the presence of some electrolysis and polarization. All of this physical and chemical research devolves upon the industrial laboratory. The investigator is fortunate if he have a thorough grounding in the elements preparatory for this work. Any problem in this whole field is well worthy of a university laboratory and no problem can fail to yield results of scientific as well as practical interest.

Similar fields of industrial research might be cited without number: leather substitutes, magnetic materials, porcelain, varnish, glass, coke, soap, non-corrosive alloys, tool steel. In each field there are extensive groups of problems each relating to material for a different special purpose and each with its special set of requirements. In each case, the university man, entering industrial research, finds his academic training, even high-grade graduate work, to be hardly introductory to the

work in hand. By digging through recent scientific literature he may find a few bits of applicable data and suggestive leads, but rarely more than this. In a few of our leading technical institutes advanced students work on actual industrial research problems and excellent results are obtained. The student takes a keen interest in his work and gets a great deal out of it, the spirit of the whole institution is enlivened and frequently both the student and the concern to which he disposes of his rights reap considerable financial advantages. If the student is careful to clear up the fundamental principles involved, even "pure" science is as rapidly enriched as by any other class of research.

In the broadest meaning of the term an *engineer* is one who applies fundamental principles to practical problems. With a thorough grounding in those principles and a taste for the practical, he rapidly becomes an expert in his chosen field, whether it be bridge-building, designing power plants, making explosives, surgery, copper reduction, banking, ceramics or radio-telegraphy. In order to become an expert it is necessary first of all to acquire a broad general knowledge of all fields related to the one chosen. Upon this must be built a thorough knowledge of the basic principles involved in that field; research is undoubtedly the best and only means of acquiring such knowledge. Then comes the technical training in solving practical problems obtained through actual solution of such problems. Finally, the expert is ready to attack any problem that he may be called upon to solve. The future of the nation depends upon the quality and numbers of its engineers. A first-class engineer is not only an expert in his chosen field, but keeps in close touch with developments in basic principles in his own field and in related fields. It must be admitted, however, that the country is full of men in positions where expert knowledge and skill would be desirable, but who have neither the thorough grounding nor an up-to-date knowledge of their chosen lines of work. May the number become rapidly fewer!

Nearly all our large industrial concerns are now in the hands of a corps of trained experts designing, superintending manufacture in its various branches, writing specifications, testing products, etc., frequently known as the engineering department. Within this department, a natural subdivision is the research division, looking after the more technical and scientific problems that arise. That division is composed largely of physicists and chemists who are experts on raw materials, on testing product, on special products, preparations,

methods and processes and on uncovering obscure basic principles and relations. Such a research division falls naturally into two fairly distinct sections, the technical and the scientific. The technical or engineering research section takes care of works troubles and routine testing and looks after the initiation of new works processes. The scientific research section properly looks after the investigation of the larger and more obscure problems requiring more extended research in more or less pure science. The technical research is conveniently located within the works while the scientific research may best be carried on in special laboratories separated from the works and largely under its own management. Technical research requires men with a taste for precision work and an insight into practical problems. Scientific research requires men with subjective fertility of mind and a firm grasp of the fundamental laws and principles of physics or chemistry.

In brief, industrial concerns provide their own research divisions, because (1) the accumulated knowledge of physics and chemistry falls far short of filling their needs and (2) university research fails to provide solutions for most of the larger industrial problems. University research might be largely directed toward problems of industrial moment without being any less scientific than the present average of university research, but the results of such research would always be unsatisfactory. In most cases, further research would be required to bring the results into shape for industrial application and in any case some one concern would wish exclusive rights to their use. It is only fair that the industry reaping the chief benefits from the results obtained should bear the expense of obtaining them.

The great strides in industrial progress are in the nature of improvements in *materials, methods* and *processes* and are chiefly, therefore, the work of chemists and inventors. The physicist investigates and tests the results of both. In the typical group of problems cited above (condenser dielectrics) the chemist develops materials of promise while physical measurements test their worth. The work of the physicist is at least as important as that of the chemist, but the credit will go largely to the former. This case is typical of the vast majority of research problems. The expert called upon to test a new invention is also usually a physicist. Comparatively few valuable results are obtained by either physicists, inventors or chemists working alone.

In the ideal industrial laboratory there must be the closest

cooperation between the physicists and chemists and indeed between all members of the laboratory staff. University research must always be done largely through individual effort due to its very nature and to the lack of coordinated time for research by either instructors or students. Some of the earlier industrial and national research organizations are on a similar individual plan. Each high-grade man is given a room or suite of rooms with apparatus and assistants and only his chief (if any one but himself) knows much about what he is doing. There is no regular meeting of the staff for discussion of results and no general assembly other than perhaps a weekly meeting to listen to a lecture by an outsider. The natural result is a tendency to wander into side issues and to become jealous of colleagues through ignorance of their work and objectives.

In some of the more recently organized large industrial research laboratories, cooperation and team work are carried to an extreme heretofore unknown. A system of weekly or biweekly conferences on each of the major lines of research promotes the interchange of ideas and a general knowledge of all the work going on, and thereby secures an excellent spirit of cooperation and comradeship. Each conference is attended by the men carrying on the work, colleagues interested in that work, a member of the patent department and one or more research engineers. The latter look out for patentable material and for results of probable interest in the works. The director is ex-officio chairman and directs the discussion along the most useful channels. Stenographic notes are taken of each conference, these notes being afterward revised, typed, witnessed and filed for reference. Such conferences effectively stimulate ideas and suggestions and keep research directed toward the chief objectives. Such effective team work in scientific research is new, but the results indicate that it has come to stay.

An occasional conference is given over to suggestions for new lines of research. If, after thorough discussion, a suggestion appears sufficiently promising, a grant to cover it is applied for and work initiated. A piece of work lasting a year and costing from two to ten thousand dollars is not to be lightly undertaken or discontinued.

Three forms of general assembly are found to be profitable in any research organization: (1) a meeting to present and discuss the work (scientific paper or technical report) of members of the staff, (2) a journal meeting dealing with the current periodical literature and (3) topical lectures in groups of three to five lectures by some expert member of the staff or outsider

on his own specialty, chiefly for the benefit of the younger members of the staff. Men who have joined the staff without much advanced university work are always a problem in the older, larger laboratories. Their advancement can not be as rapid as it might had they a full university training, it is difficult for them to drop out for further university work and, unless some such lectures are provided, the less mature men are liable to stagnate.

The *technical research* wing of the research division of a large concern is properly about equal in size or somewhat larger than the scientific research section and is made up of chemists, physicists and engineers. Their work is necessarily varied in character. It ranges from chemical analyses of raw materials and the testing of products to the elimination of works troubles and the testing and installation of new manufacturing processes. Such work requires men with a taste for routine testing, precision measurements or for the application of scientific data to concrete problems. On the other hand, men with high originality and a tendency to theorize belongs rather in the scientific wing of the research division.

Another function of the research division is to prepare men for the higher executive positions and to train specialists to take charge of special fields of advanced technical research. Men who have had a full academic course, supplemented by several years of research work in an industrial laboratory, make the best of timber from which to select *executives* and high-class *specialists*. There is at present a strong tendency to fill the higher-salaried positions only with university men with research experience and such is the avowed policy of a number of our largest manufacturing concerns. Workmen in the shops may rise to be foremen, but no farther; superintendents, chiefs of divisions and heads of departments must be university men with technical experience.

The best *preparation* for industrial research as a profession is a thorough and broad grounding in the fundamental principles of the field chosen. The student should not specialize too early nor too highly or he will fail to obtain command of related fields of science or engineering. In quantity and breadth of academic preparation the standard to be chosen is about that required for the doctor's degree in our best institutions. The new men preferred at research laboratories are men with doctorates who have published half a dozen scientific or technical papers. Men with less preparation are under a handicap and do not advance as rapidly as a rule.

Summary

The essentials in a successful modern industry are capital, labor and the technically trained expert. Only rule-of-thumb, relatively unprogressive concerns are possible without scientific specialists.

The numerous departments of a large concern require the services of a wide variety of experts. Engineers are experts in the application of organized knowledge. The research division is a branch of the engineering department and consists of two wings devoted to scientific and technical research.

Technical research is devoted to the testing and specification of materials, checking product, initiating new processes and the elimination of incidental works troubles.

Scientific industrial research is devoted to the extended investigations of basic principles and relations to the more obscure and fundamental works troubles and to the development of correct testing methods.

The research division as a whole is, in addition to the above, a training ground for men for the higher executive and technical positions.

The best academic foundation for industrial research as a profession is a broad and thorough grounding in the fundamental principles and relations in the chosen field of activity.

THE TUTORED FARMER

By Professor W. O. HEDRICK

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THE much preached but little practised educational precept that "learning should be by doing" was never more boldly applied than in the contemporary endeavor to give technical instruction to farmers and farmers' wives upon their own premises. Farm demonstrations, or agricultural extension work as this movement is known, indifferently, acknowledges the truth that farmers are visualists rather than auralists in their methods of learning. The motor car, telephone and cheap railroad rates have of course had their share in making this new instructional scheme practicable, but after all the preference of the farmer for "being shown" rather than "told" is the basis for the new system.

Farm demonstrations as a systematic way of teaching farmers seem to have been first employed by the late Seaman A. Knapp two decades ago in undertaking to show southern farmers how to escape the evils of the boll weevil in their cotton fields. The technique of the demonstration as employed then by Dr. Knapp and as now used by thousands of county agents and extension specialists is the same and consists in doing upon the farmer's farm or in his house the thing which it is desired to teach. Feats of this sort may be applied to any one of the numerous details which make up the farmer's craft, but their purpose is always instructional and their methods are invariably those of performance.

"Putting on a demonstration," as the act of teaching in this way is called, requires the accomplishment by the demonstrator under the actual conditions of the farm process—the thing—tile laying, tree pruning, crop harvesting or what not—which he wishes to make clear, and preferably to a group of farmers since this extends his message. More than 500,000 visits of this sort were made to farms in 1915 by demonstrators, the last year in which records have been tabulated by the Federal Department of Agriculture.

The farm demonstration method of instructing farmers has proved revolutionary in the realm of agricultural education. Formerly the most successful agencies in this sphere were the

farmers' institutes, technical bulletins, the agricultural press and agricultural educational institutions. The last three of these still remain, but the institute, for a quarter of a century the supreme method of reaching the adult farmer, has surrendered everywhere its supremacy to the newer method of instruction.

Not only has public authority specialized itself to reaching the farmer by this method of instruction, but railroads, banks and certain manufacturing establishments of prominence throughout agricultural regions employ officials who are devoting themselves to this propaganda. The International Harvester Company, as an instance, "puts on" many scores of demonstrations annually in furtherance of its belief in this method of teaching. The method has been successful, too, in accomplishing its purpose. As is well known, the farmer is the most conservative of men. He still hugs himself with the delusion of personal independence. Dean Bailey, of Cornell, tells the apposite story that on leaving for home after conducting a very successful farmer's institute in western New York he overheard the following conversation between two members of his audience as he passed them outside the doorway. "Well, Sam, how did you like it?" "Oh, I don't know," replied the other, "It hain't hurt me none." In spite of this robust self-independence which grows from the farmer's natural isolation in both a business and a social way, he has taken to this new form of instruction. He attends the demonstrations, as is shown by the statistical report from the department of agriculture quoted above, that in 1915 more than 2,959,700 came to these gatherings. The farmer's approval is shown also by the fact gathered from the same authority that he contributed directly during the year, through his county appropriations, a round million of dollars in support of these demonstrations. Many individual county demonstrators, too, in token of their worth to the contributing farmers, receive vastly larger salaries than colleges or universities can afford to pay.

Furthermore, the farmer is anxious to be taught. Not so long ago but that it is a matter of easy memory, farmers spurned anything savoring of "book farming" as applied to their business. Until 1900 our agricultural colleges were puny affairs. Attendance was not from those who intended to follow agriculture, and as late as 1908 Mr. Prichett, of the Carnegie Foundation, in his annual report, declares concerning these institutions—"they have not yet found themselves." Science applied to agriculture has overturned this situation and

the new vocabulary of farming is replete with terms such as these: "bacilli culture," "butter fat tests," "balanced rations," "orchard spraying," "soil liming," "labor incomes," "major performance standardizations" of various sorts, "moisture content," credit associations, etc. Even the most self-confident farmer must admit that he knows nothing about these, and his necessities have rendered him a docile pupil. In addition to this the enormous costliness of contemporary agriculture has forced the farmer to utilize every device to lower expenses. Farms are no longer given away under homestead laws. Quite the contrary—it can easily be demonstrated that farm lands have risen more in price during the eighteen years of this century than during all our previous history. The operator of a costly farm may not wisely omit any helpful teaching which will enable him to make a profit on so much investment.

A demonstration may consist of an object lesson in tiling a field, in kitchen drains and sinks, in the "cold pack" method of fruit and vegetable canning, in how to plant a garden, or in any one or the other hundred additional features of the farm and farm household processes. Usually there is an immediately useful product which results from the lesson—as cans of produce where canning demonstrations have been "put on"—and these go far to create enthusiasm for the belief that education and actual life may be brought close together.

Education "carried to the people" as this is, must necessarily be expensive since, like the "circuit rider" of old, the mentor of this new learning is constantly in the field moving from place to place. Unlike the history of most educational innovations—a history of private sacrifice and initiative until success is achieved, whence adoption is immediate on the part of public authority—the farm demonstration movement received governmental support from the start. An appropriation made by Congress in 1903 for combating the boll weevil in Texas was handed over in part to Dr. Knapp for his demonstrations experiment. Annual appropriations followed from Congress for carrying on what was known as the "Farmers' Cooperative Demonstration Work" in the South and in 1912 appropriations were made for carrying on the same work in the North and West. The Smith-Lever Act of 1914 is the crowning work of government in this great undertaking, and since it not only furnishes the funds, but also the plan of administration for the enterprise some discussion of its terms are necessary.

A sum approximating a half million of dollars was to be

distributed among the states during the first year of this appropriation, augmented by half million increases during each of the eight years thereafter. This is a summary of the finances of the great law. Furthermore, since an amount corresponding to the gift to it from the federal government must be raised by each state, one easily sees that eight millions in toto will be available for carrying on the work in 1922–23 and during each subsequent year.

So large an amount as this devoted to a single purpose must needs have unusual administrative machinery and it is insisted by the law that a separate division or school known as the extension school shall be created in each agricultural college through which these funds are handled. A special bureau in the federal department of agriculture to administer its end—the States Relation Service—and the directive apparatus of the new law is complete. The trend which this new extension effort should take is shown by the further provision that "extension work shall consist of the imparting of information through field demonstrations, publications and otherwise."

The county agent, as he is called, is the central figure in this mechanism. He is the immediate representative of the Smith-Lever fund and farm demonstration system to the rural locality; he is the chamber of commerce secretary in the open country; the "heading up" agency for all the organized agricultural activities of the county. In 1916 there were 1,225 farm agents employed in the various counties, and 430 women employed in farm household demonstrations, leaving only 1,695 agricultural counties still unprovided with these representatives.

The county agent, whether man or woman, is first and primarily the farmer's adviser and preceptor. He is the interpreter of the agricultural college teachings and the experiment station discoveries to the farmer. The homely title "farm doctor" was originally thought to be the term which properly characterized him in his attitude toward professional activities. It is usually thought best that he must be a graduate from an agricultural college, but whether educated in science or not, he must certainly be a practical farmer in order to satisfactorily advise. He must have many of the gifts of leadership too, as the further discussion of his work will show.

As an adviser there are no problems pertaining to agriculture which the county agent may not be called upon to solve. A short summary of the typical agent's services shows him engaged in the judging of live stock and seeds, in the encourage-

ment of under drainage, in illustrating the cultivation, pruning and spraying of fruit orchards. Everywhere he advises with regard to tillage, time of crop planting, varieties, nature of cultivation and harvesting methods. He is also the counselor as to when to market, what rotations to pursue, how to secure credit, and the proper use of machinery. The epithet "general practitioner" well describes this cyclopedia afield and the motor runabout and the telephone are his indispensable allies.

But the county agent is more than an adviser, he is also a teacher and, like the practical laboratory man that he is, he believes that pupils learn best when they conduct their own experiments. Through demonstrations, therefore, upon their own premises, he undertakes to see that each farmer benefits from a practical experience. At this point arises what is probably the most cardinal of the pedagogical precepts which have come up in this new species of teaching and this is that the farmer reacts to no other educational stimulii so quickly as through being shown the successful achievements of some neighbor farmer. "Pick up in one place the instance of a successful farm achievement by one farmer and carry it to the farmers in other places," says an experienced demonstrator, "and you will win their confidence and adherence at once." The county agent undertakes to effectivize this "teaching from example."

"To put on a demonstration," therefore, is the county agent's way of making his teaching agriculturally read by as many as possible. Demonstrations themselves are helped by contact teaching of every sort, such, for example, as automobile and train trips to places where good farm enterprises are to be seen. Most customarily perhaps they are "put on" by being arranged for in advance through getting some farmer to make himself a model in performing some farm feat. It may be the growing of alfalfa, or the using of a fertilizer, or the raising of a special variety of animal or grain. At any rate, at the proper time interested neighbors are motored in and the lesson to be taught is presented.

In this work the county agent is frequently helped by the subject-matter specialist furnished through the state college or the federal Department of Agriculture. Since these subject-matter specialists are the "first helps" to county agents, and indeed are sometimes considered to have their whole usefulness through the teaching field that the agents' need furnishes them, a word of description of these specialists is necessary.

Agricultural colleges and departments of agriculture every-

where have upon their staffs these "teachers on mission" as they may be called, representing one or the other of the various college departmental divisions. They are usually of professorial rank in the college and indeed differ from the usual departmental member only in the respect that their work is afield rather than in the class room or laboratory. It is for them to be ready for the summons from the permanent agent in the field to hasten thence with the desired special message. This done, the subject-matter specialist returns to headquarters to await another call.

However, neither of these two forces—the one on mission nor the one permanently in the field—relies solely upon "occasions" to shape their activities. At stated intervals members of both forces assemble together to shape permanent programs or "projects" of work, as they are called, to be carried thenceforth into practical effect. These programs include a wide variety of farm interest and are entered into with the deliberateness and formality of a general staff preparing a campaign. The specialists are indispensable, therefore, to the county man to keep him freshened in information and also to enable him to systematize his attacks on the farm problems which are to be solved.

In the second place, the county agent is the organization promoter of his county. A slight calculation will show that it is a physical impossibility for any teacher to maintain or even to acquire a personal touch with every farmer in a county. Therefore it is indispensable to the county agent that he perfect some other means of transmitting the message than himself, and the organization of his followers is the device. Sometimes it is only a matter of the federation of existing organizations, since in many country communities farmers have already found their way into concerted action and a redundancy of organization is as bad as too much of anything else.

Farmers indeed are becoming conscious of the merits of united action. The Roosevelt Country Life Commission of 1907 suggested "organization" as a cardinal method of improving country life. The organizations suggested have certainly been forthcoming in recent years both of the sort which express the farmer's passionate and immediate desires, such as the milk producer's unions near our large cities, or the nonpartisan league of the Dakotas, but also organizations more firmly rooted in the farmer's needs, such as the granges, farmers' clubs, and the cooperative association of various sorts. Agricultural societies—trade associations they would be called

in town—have existed for generations among farmers. Indeed, it is probable that there is no branch of agriculture, however, small or remote but what it is organized more or less closely for educational and promotive purposes. But the present-day attempts to organize farmers by communities in respect to all their interests, and especially to develop in them class consciousness such as that possessed by unionized labor, promise to become the dominant form of organization in the open country in the near future.

The farm bureau, as the variety of organization is called which the county agent promotes, has its members, whether individuals or associations, acting as teachers or sponsors placed in all parts of the county, and at the center a "clearing house" for ideas and teachings is formed available to every one. It is, in brief, the chamber of commerce idea carried into the rural neighborhoods. The bug-a-boo "class development in a republic" which this program arouses resounds feebly against the movement, since the agricultural class already exists and the sole question is should it be organized into efficiency or remain disorganized and impotent. Usually the headquarters of the farm bureau is in the county agent's office in the local courthouse, and here its members meet at intervals to discuss projects or decide upon undertakings in the betterment of the county farming.

The demonstration movement does not expend itself solely upon the farm and farm household, but reaches out in a well-organized way through boys' and girls' clubs to the youth of the farm regions. In both forms of this junior extension work, as this activity is called, the clubs derive their funds and take on a similar administrative system to that of the county agents just described. The end in view is inspirational rather than the immediately practical. Boys' and girls' clubs are auxiliaries to the agricultural schools and endeavor to furnish stimuli of the agricultural sort which will keep young people interested in farming. Nevertheless, in the frenzied farming which took place last spring resulting from the food famine fear, these associations of children became immediately practical, since they took over a large proportion of the school gardens which were then so important. Indeed, the fifteen per cent. increase in agricultural production in 1917 over any preceding five-year average in our history may be attributed in no small degree to the efforts of the extension specialists, both of the junior and senior sort. Congress made large especial appropriations—as did certain state legislatures also—to both

these classes of workers during each of the two years since our entrance into the war, and few expenditures seem to have been better warranted or to have given better satisfaction than these.

An educational institution, of such vast proportions and unique scope as that provided by the Smith-Lever Law, has seldom been established upon so small a basis of experience. Much experimentation is therefore inevitable. Already serious problems have arisen as to the proportions of authority between the federal Department of Agriculture and that of the different states. Furthermore, the activities of the teaching staff are too largely shaped by circumstances rather than in accordance with a fixed program. Suitable instructors have been difficult to obtain, not only on account of the inherent difficulties of the new scheme of instruction but also because of the man absorption of the war. Extension teaching in general, however, has proven its merits and has become a permanent part of our educational system, and there seems to be little doubt but that the special form of this new style of teaching which makes use of the demonstration method will find its place and maintain itself in its proper field.

BIRD MIGRATION IN ITS INTERNATIONAL BEARING

By JOSEPH GRINNELL

DIRECTOR OF THE MUSEUM OF VERTEBRATE ZOOLOGY OF THE UNIVERSITY OF CALIFORNIA

OF all natural assets bird-life is least localized. Birds are in large part migratory, and many kinds move over great extents of country according to regular seasonal schedule. They cross boundary lines of all sorts, and traverse territory always in response only to their own critical requirements as regards food supply and climate. Faunal boundaries rarely coincide with political boundaries.

It would seem scarcely necessary here to argue the value to any community of its native bird life. We have come to recognize in wild birds sources of recreation, both physical and mental, of æsthetic appreciation, of practical aid in insect repression, of service in reforestation and spread of useful plants, and of food for ourselves.

The great majority of our waterfowl are migratory; and the pursuit, capture and shipment of these in particular, has meant wage-earning occupation for some thousands of men in the United States, for at least a part of each year. In California alone, according to statistics of the State Fish and Game Commission, wild ducks were sold on the markets in 1912 to the value of $250,000; about one million ducks in all were shot, presumably all used for food; and over one and one half million dollars were expended in the pursuit of these on the basis of recreation—maintenance of gun clubs, traveling expenses, ammunition, etc.

I have here attempted to convey an idea of one of the values of bird-life in terms of dollars; for dollars seem to constitute the only ready measure of value comprehensible to every one. Some of the values of birds just referred to, it is of course impossible to express in connection with the dollar sign. While the total monetary value of birds is not to be figured in hundreds of millions of dollars, as with certain other natural resources, it may properly be asserted, I think, that total disregard or waste of an entire asset of relatively small quantity is just as poor business as disregard or waste of a small part of any large asset.

I hardly need try to demonstrate here my conviction that it *is possible,* without special care, to levy an annual draft upon those birds for which we may have use dead. I will only refer to the biological principle that rate of reproduction has been established at a point in excess of sufficiency to meet the maximum probabilities of casualty. The persistence of the species has been assured, at least under the natural conditions obtaining immediately heretofore. The interpolation of the human factor would seem to have influenced the natural balance on the whole in favor of increasing bird population, this because of the customary destruction by humans of other animals normally predatory upon bird-life. Of course there *are* cases where cultivation of the land by man, or the removal of forests by him, has affected adversely, and inevitably so, the persistence of particular birds; as, for instance, the mountain plover and the passenger pigeon. But there remain very many valuable species which have not been so adversely affected by man's presence and some which have even benefited; and these are the ones from which we can expect contribution to our needs without attention on our part save for regulation of our own rate of draft upon them.

Let it be accepted, then, that bird-life does comprise a natural asset worth conserving, to the end that it may become a thing producing regular annual income. If many of our important species are migratory, how can proper conservation be secured without cooperation between the several countries through which such birds travel during their annual migration? Here in California, in the early days of bird and game legislation, each county of the state formed its own code of laws irrespective of its neighbor. No thought was taken towards adjustment of regulation with a view to conditions throughout the entire state. In 1861, for example, the shooting season for waterfowl and upland game birds in Los Angeles and San Bernardino counties opened on August 1, whereas in adjoining counties it did not open till September 15. The earlier date cut into the nesting season of the birds to the injury of the breeding stock in all the counties. But adjustments have now been made, by which judicious treatment is accorded to the game birds throughout the state, although this has meant the curtailment of shooting altogether in some districts—this, however, strictly in the interests of the state as a whole.

Can there be any less justification for the cooperative conservation of bird-life as between nations?

One of our wading birds, the golden plover, at one time so plentiful at certain seasons along the Atlantic Coast and in the

Mississippi Valley as to be marketed in New York City by the barrelful, repairs during its short summer breeding season to the Arctic coast of North America from Alaska eastward. There it finds safety for its young, as well as adequate food. In late summer the flocks of golden plover, adults and young, start on their southward migration, going first eastward to the Labrador coast, thence to Nova Scotia and the coast of New England; then they undertake a journey of 2,500 miles southwards across the Atlantic Ocean to Brazil, and thence proceed to the plains of Argentina. In the last named country the birds spend their winter time under summer skies, then start northward in the early spring along a course different from that followed in the fall. Passing through northwestern South America and through Central America they cross the Gulf of Mexico, follow up the Mississippi Valley across the central United States and continue on through central Canada to their breeding grounds, on the Arctic Coast. In this annual circuit of more than 16,000 miles, as worked out by the late W. W. Cooke, of the United States Biological Survey, the golden plover comes under the jurisdiction (where any regulations at all exist) of no less than seven different nations.

This particular game bird does still exist, but probably in not one one-hundredth part of its original numbers—for this reason: It happens that the migrant throngs were intercepted without let or hindrance by market hunters at at least one critical point on their annual circuit, the coast of New England. Whole flocks were annihilated without regard to the principle of maintenance of breeding stock. This could not help but injure the supply of plover at all other points in its range.

Again let it be said that there is no doubt but that native birds of any sort can be so treated that an annual crop can be gathered. This has been done from time immemorial with permanently resident species of game birds in Scotland, Holland, and other European countries.

Happily, the laws of the United States are now closely approaching the ideal in their treatment of birds as a national asset. But no one country alone can handle the problem of the migratory species. Migratory birds constitute a common property among nations, and one which should be administered in common and shared with due regard to all the factors involved. An important step has just been taken in this direction. In 1916 there was formulated as one provision of a treaty to be entered into between the United States and Canada a migratory bird clause, under the provisions of which each of the two countries is to adhere to a program of absolute protection of

migratory insectivorous birds and of maximum limits of open seasons on migratory game species. The final ratification of this "migratory bird treaty" was completed by our Congress, June 6, 1918; the Canadian sanction had already been formally given some months previously. As far as my knowledge goes this is the first really important accomplishment as regards international agreement in the regulation of bird conservation. It is the beginning of a system which should in all reason prevail among countries throughout the world.

In the birds of migratory habit we have a valuable asset which cannot be administered advantageously in any other way than through international cooperation.

THE HOME OF THE SOVEREIGN WEED

By Professor E. M. EAST

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ARE you a worshipper at the shrine of My Lady Nicotine? Have you offered incense with a real Havana? Performed the rite with all its proper ceremony—the tender removal of the fancy label with many misgivings as to whether the offending girdle has left its scar, the careful, deliberate clipping of the end, the final Promethean touch, the first ecstatic inhalation, the contented smile? But no, no smile, this is a serious business. If such has been your lot, and you are not an unworthy devotee, you have realized there is both truth and poetry in the line, "There's peace in the Laranñaga," that in the Laranñaga or any one of a dozen other brands unsung by Kipling from the Pearl of the Antilles, there is something not found in the baneful product of the average domestic factory.

Whence comes the delightful fragrance of the true Havana article, so different from the tarry odor so often met in the product of other lands? Why does the single isle of Cuba, but ninety miles off Key West, yield a plant unique, characteristic of itself alone? It is a fact, the theme of song and story. But why?

One hears it attributed to some mystic instinct of the grower or to the secret genius of the manufacturer. It is ascribed to the climate, to the soil, to the variety of the plant. I would not have the hardihood to deny all virtue to any of these. Doubtless each is a contributing factor, though they vary greatly in their contribution. But, in my opinion, the really effective agent has never been described. Others may not agree with me, and in truth the cause of such a fugitive, indefinite thing as quality in whatever pleases the eye, ear or palate is difficult to prove. I will give my version of the story; one may take it or leave it.

Four centuries have passed since the white race took up its burden in Cuba, four centuries of war rather lightly flecked with peace. But time has dealt kindly with the island. The American touch has of course improved its ideas of sanitation and education, but the people and their customs remain unaltered. It is true buccaneers no longer ply the Spanish Main,

and Spanish misrule—less bad than it is pictured, by the way—is no more; but the pirate still stands behind the counter of the city shop, and the free and independent citizen is fleeced in the same old way by his duly elected public representatives, to whom the city fathers of the same ilk in certain of our own cities might well go for instruction.

During this time the country has been a melting pot for more varied ores than even the United States. The population at the present time is something over three million. The census says seventy-one per cent. is white, a surprising thing to the visitor making his own observations until he learns that the obliging census-taker inquires of each whether he is white or black, and black indeed he must be if he does not reply *blanco.* The educated classes are largely of Spanish descent, of course, but in the mass of the population there is such an intricate mixture of Chinese, negro and Indian that one hesitates even to make a guess as to the origin of a particular individual. For this reason one can not characterize them as a people. They are too varied, physically, mentally and in disposition. Those of Spanish blood and even those having a considerable admixture of Chinese have a marked ability along the lines formerly accredited to the down-east Yankee. They are sharp, shrewd, observant and witty. It is a common saying that the Jew starves to death when within reach of their competition.

But since it is the barefooted inhabitant of the palm-thatched cottage, the representative of the common people, who raises most of the tobacco—indeed all of the tobacco of the finest quality—one can hardly impute to him either uncanny skill or hidden knowledge in bringing it to the forefront of the world's markets. Let us give the tiller of the soil the good word he deserves, for in many ways he is a lovable person, kindly and hospitable, but let us look elsewhere for the reasoning of our riddle.

On the other hand, some considerable credit for the excellence of their product does belong to both the Cuban manufacturer and his workman. The former, keenly alive to the value of a little hocus pocus with the American buyer, plays a very practical tune when he emphasizes the difference in flavor of each vintage, the varied quality of the product of the several districts, or the care with which each blend is made, with a polite but condescending intimation that the way he does it is beyond the ken of ordinary mortals. As a matter of fact, there is a modicum of charlatanry in tobacco judging as in wine judg-

ing or anything else of similar type where personal equation is so great. The Cuban manufacturer does take the necessary time to finish every process, no matter how much is required—something his American rival does not always do—but to believe he has kept any business secrets to himself requires more perfect faith than I possess.

But the Cuban cigar maker, that is another thing. He is a master-craftsman, an artist. *His* product is not hammered together like that of the American workman, who bunches his filler carelessly, hides his misdeeds in a binder of no special size or thickness, and finally courts ruin by crushing the whole thing in a mould. Instead, he actually builds his *tobaco,* as the Spanish call it, piece by piece, carefully spreading one small leaf around the other and manipulating them deftly with a single hand, till, perfect in shape and size, it is ready for the wrapper. When, with some paternal pride, he holds it up for final inspection, one can hardly repress an exclamation of admiration at the exactness with which it matches its fellow. Truly in this case the laborer is worthy of his hire.

Were it not that we have somewhat overstated the case of the workman in the states, one might suppose that the key to the problem lay here. But though probably seventy-five per cent. of the American cigars are abominations concocted of the mould and binder, still there are numerous factories working after the Cuban model without obtaining the Cuban result. We must look further.

The climate of Cuba is wonderful, perhaps the most wonderful in the world. No ice, no snow, no wintry blasts. Sometimes a January *norte* bringing a temperature of 50° F. makes the inhabitants pull their garments closer, but the mercury rarely sinks lower. It is continuous spring. No sticky, humid Florida weather, just delightful bracing air somewhere between 70° and 90° in the shade. In the sun it *is* hot; but it is a comfortable, refreshing sort of heat, the kind we in the north get on one or two days in June, when there is wholesome contentment in just basking there carefree and indifferent.

It may be that climatic conditions loom large in the matter of perfecting their tobacco. It is known that an even temperature and a relatively constant humidity are necessary factors for the foundation of high-quality leaf. Their control furnishes the reason for the immense sums spent in Florida and Connecticut on the cotton cloth under which is produced the so-called shade-grown types. And further, it must be an immense advantage on the manufacturing end to be able to handle

the cured product at any and all times without being continually on the jump to approach correct conditions by supplying artificial heat and moisture. To be sure, Tampa and Key West have similar climatic conditions, while, with all due regard for the proprieties, their cigars are still those of Tampa and Key West; but we must remember that these manufacturing centers seldom have to deal with a high-grade Cuban leaf, so that a fair comparison can not be made even on the manufacturing end and none at all as to the effect of climate on production of the natural leaf.

But what can we tie to in all this? The grower, the manufacturer, the workman, do their bit, as one might say; the wonderful climate is a mighty factor; nevertheless, as efficient causes of Cuba's preeminence in tobacco, they are not convincing. And varietal difference can be left out of consideration, for the Cuban varieties have been smuggled out again and again and tested in every country under the sun. The answer is that we have considered everything but the "hoyo," and the *hoyo,* the "hole" made by Nature in their limestone cliffs, is the efficient cause. You will recognize the term in the name of the celebrated brand "Hoyo de Monterey," cigars made originally from tobacco grown in the *hoyo* of Monterey. These limestone pits are Cuba's secret, the home of the really fine product. Cuba raises much other good tobacco, and, to tell the truth, much tobacco in her eastern provinces about which the least said the better, but the *hoyos* are the workshops for Nature's best. Why they are but seldom visited by the Havana nicotine magnates and known only by rumor to American tobacco men, I do not know, but I have recently had the pleasure of making a personal pilgrimage to two of the most famous spots and was told there that I was one of the first Americans to make the trip.

We left Havana, three of us, about 6:30 in the morning in a Henry Ford production, fortified only by a single cup of *cafe con leche,* that peculiarly flavored coffee that is really a Cuban institution. We were driven clickety-clack by one of those reckless corner-cutting chauffeurs with which Havana is infested, whose almond eyes betrayed an ancestor from the Celestial Kingdom in the not too distant past, and who nearly brought us to grief at the first turn by running into a native who was trying to get some speed out of his Andalusian mule by screaming, while wielding the goad, "I will beat thee! I will beat thee! If thy skin were that of a holy Saint, still would I beat thee!" Luckily we missed him and sped out into the highway

to Pinar del Rio with grins on our faces and curses in our ears.

Though with marvellous ingenuity the infernal chauffeur jolted us squarely through each uneveness in the road, we felt that the trip was "not too bad" as the Cubans have it, when we flashed out from under a long avenue of royal poincianas loaded with their giant beans and our eyes met the fascinating outline of the distant mountains, across long plains dotted with feathery plumes of the royal palm.

We breakfasted, a typical Cuban breakfast of six or eight courses, at San Diego de los Baños in a wonderful inn some centuries old, then on to Pinar del Rio, the center of the tobacco district. From here our way wound up through shale mountains covered with dwarf pines, as different a scene from that of the morning as well might be. Typical Virginia hills they were, and if rifts in the rocks and turns in the road had not given us glimpses of the tropical verdure below, we should have thought we had suddenly been transported there on Suleiman's magic carpet in the moments we had nodded from the effects of somnorific old Sol.

Down again and up like the King of France with his ten thousand men, thirty miles beyond Pinar del Rio we reached our goal, San Carlos del Valle de Luis Lazo, perched on a little plateau at the foot of the limestone cliffs of the Sierra del Camo. Here, thanks to the hospitality of the "squire" of the little village, good old Don Andres Carvallo, we spent the night, and were ready early the next morning for our trip to two of the *hoyos*, Hoyo Valteso and Hoyo Martel, for each of the thousand or so of these places has its individuality marked with a name of its own.

As the cliffs seemed to rise absolutely vertically some four or five hundred feet, there was some speculation as to our ability to make the climb, but we were assured by Higinio, our native guide, that he would take us up one of the easy trails—one used for many years by oxen. As we plodded up the narrow, twisting, stony path, rising at an angle of fully sixty degrees in places, our respect for the climbing ability of the ox increased. In response to our questions, Higinio informed us that it took at least a year to train each ox, schooling him in his task by placing him between two *practicos* that had previously learned their trade. In other *hoyos*, those really isolated by the steepness of the cliffs, they are carried in when quite small calves, and spend their whole lives there before the plow and harrow.

As the top was reached and we peered down, between the trunks of the *palmas de los sierras*, and the branches of the

ceibas covered with bromelliads and an occasional orchid, we caught our first glimpse of the *hoyo*, a pit in the limestone rock, apparently the crumbling remnant of a cave with the top fallen in. It seemed to cover about an acre, though in reality it was eight times as large. The level floor was dotted with green spots which we knew must be tobacco, though we could have hazarded no such guess from its size, and at one side the curing barn, a palm-thatched affair about fifty by twenty feet, where the leaves are hung to dry before being packed into the odd little palm-covered bundles ready for their journey to the Havana market. The picture was a gorgeous riot of color under the tropical sun, but even so, there was not that peculiar feeling of awe which came when we had cautiously picked our way down and obtained the view from the floor. I have sought for a simile, but have not found it. The *hoyo* is a thing unique. Imagine a prison of limestone cliffs towering abruptly five hundred feet. Above, the southern sun peeping from a cloud-bank of fleecy white, as if inquiring the reason for this third American intervention. At right, at left, in front, behind, the bleak wall, with only here and there a famished palm or green-barked *ceibón* struggling for a foothold, or perhaps a clump of fern and moss screening a soft-voiced dove or a black-coated wrangling Jew bird, the echoes of whose vocal aspirations resounded back and forth. Below, the tidy garden with drooping rows of green broken at times by a spot of pink where a Cuban nettle flaunts its flag of warning. Surely it is a garden of gnomes, where nightly they water their seedlings with a magic essence, coaxing them to distil the fragrance in their leaves, that dead and gone they may fulfill their appointed lot in bringing solace and contentment to the tired business man—really given away at three for a dollar gold, in Havana.

The tobacco, botanically speaking, was in no way different from the same variety grown in Connecticut. There was the same habit of growth, the same shaped leaf, the typical flower. Only the size was something new to our experience. It was dwarf, tobacco in miniature, two feet high at most, with seven or eight delicate little leaves scarcely long enough for a man's size cigar. We saw none of the cured product, but were assured that the yield was about 300 pounds per acre in a good year, and (with considerable pride) "the price, Señor, one dollar and a half a pound at the plantation." When we thought of the 1,800-pound yields of the same variety on the level fields of Connecticut, and glanced at the towering cliffs, emblems of the difficulties here encountered, we wondered why the price was

not multiplied by twenty, although, as a matter of fact, it was greatly in excess of that obtained on the island for other tobacco.

We stopped a moment on our way back at a *semillaro*, a place cleared near the top of the limestone cliff for raising seedlings for the *hoyo*. This is done, we were told, because fungus attacks are less likely at the higher altitude. Rather an unkempt place it was, with here and there a yam or taro plant showing that the workmen did not forget their own wants in the midst of their labors.

Back to Luis Lazo and a midday breakfast to which we were duly attentive. Afterwards a visit to several *ensenadas*, tobacco plantations outside the *hoyos* where a primitive sort of irrigation is used. Open troughs radiate from a platform at the water's source—in this case a river—and a patient old nag hour after hour hoists a laden barrel to the center of distribution, a hogshead reservoir some fifteen feet up. The tobacco here was larger and from the agricultural point of view much finer than that in the *hoyo*. The plants were three or even three and a half feet in height and the ten or twelve leaves, characteristic of them, were sometimes sixteen inches long. They were just in the midst of the picking, and we saw leaves in various stages of drying, hanging in the different barns. These buildings, if such they can be called, interested us very much. I do not know whether it has any effect on the quality of the product, but it is clear that these affairs with their long sloping roofs of palm leaves through which the air can pass at any point are ideal for the purpose for which they are intended, provided no torrential rains occur at the wrong season of the year and start the half-cured leaves to rotting. One other thing here was not without its attraction to our northern eyes, as illustrating the efficient use these people back in the mountains make of their natural resources. We were already aware that the royal palm might as aptly be called the people's palm, since it furnishes the Cuban with his entire habitation, with part of his furniture and clothing and, through the intermediation of his pig, with food, yet here was another valuable use right in line with our inquiry. The *tercios* or bundles of tobacco are so neatly packed away in palm-leaf envelopes that they undergo a perfect case-curing and reach the Havana factory practically ready for use. And further, the *tercios* are bound with a native rope, a product of another tree right at hand, the *ceibón*. A very good rope it makes, as strong as hemp and not half so troublesome to prepare.

Regretfully we tore ourselves away from the magic attractions of the mountains and sped to Havana. We had had a glorious trip, a trip of real discovery, one might say, and were duly thankful for the memories we carried with us. Pleasant they were, though rather disconcerting after there was time for thought. We had seen the *hoyo*, the one place in the world where they raise perfect tobacco. But had we pried into Cuba's secret, after all? Again and again came the question, why does the *hoyo* raise perfect tobacco? There is no question about the fact; the manufacturers admit it; the growers take pride in it. The price proves it. If more conclusive proof is wanted, it comes from the *hoyos* themselves. Would such a place as the Hoyo Palenque, surrounded by cliffs over a thousand feet high and reached by seventy separate ladders, have been cultivated for over a hundred years if it did not produce a superfine product? There is but one answer to this, but the reason is not so easy. I believe I have unriddled the riddle, but mark that I only say "believe."

The limestone cliffs give their aid of course, since tobacco must have a slightly alkaline soil. But then lime is not a scarce article in this world of ours and its effects can be duplicated elsewhere. Again, there is the sterility of the peculiar type of sandy soil which makes up Cuba's good tobacco land. It may have unique chemical properties that contribute to the end result. Since they have never been studied carefully, one can not say, but this does not seem a necessary assumption. The fact that there is that agricultural ideal, a perfect climate, backed up by a sterile soil of proper physical constituency, is all that is necessary to account for the generally excellent tobacco of certain areas of the celebrated Vuelta Abajo. Doesn't it seem like an agricultural paradox to attribute the excellence of a product to the sterility of the soil? It is the truth, however. Several years ago it was found that a tobacco plant produces about the same quantity of the essential oils that give the leaves their aroma no matter whether certain of the conditions under which it is grown be good or bad. In other words, if a plant grows to be eight feet high and has leaves twenty-six inches long, it produces only about the same amount of essential oils as when it grows two feet high and has leaves eight inches long, other things being equal. Now it is a noteworthy fact that while Cuban tobacco under shade in Connecticut meets the first of these conditions, the average Cuban plant hardly approaches the second. The Cuban plant is a dwarf, and packs into its small self as much of the essentials of real

quality as its giant sister in Connecticut. Here again, however, our interpretation fits Cuban tobacco in general. The conditions are met just as neatly in the *ensenada* as they are in the *hoyo*, so we still seem far off the mark. This is not the whole story, for we must remember that the *hoyo* has and uses all these advantages as a basis upon which to build its own perfecting qualities.

The *hoyo* itself is the secret of the matter. Why do they grow tobacco under shade in Connecticut, Florida and even Cuba? Simply because it conserves moisture and keeps the temperature and humidity constant and high. This the *hoyo* does naturally with its limestone cliffs, having withal the immense advantage of direct rays of the sun at a considerable altitude, factors known to be essential to other crops besides tobacco. And it has the sun when it needs it, enough and no more. From ten o'clock until three it shines directly on the plants, storing up food in the leaves for elaboration during the night, while from dawn until ten and from three until seven, there is indirect light due to the protecting cliffs. It is a stage setting that could not be more admirable from the standpoint of plant physiology, a perfect fulfillment of what are known to be the conditions required by the tobacco plant.

The reason why other countries can not compete with Cuba in producing the fragrant weed, therefore, is not so difficult to see. They may improve their methods of cultivation and manufacture, select carefully their soils and climate, may even imitate conditions artificially with tents and tent-poles; but they can not hope to duplicate the finest product until they find a wizard genius who can transport the ancient *hoyos* far beyond the sea, and train the sun to obey his word as did Joshua of old.

VITAMINES AND NUTRITION

By Dr. H. STEENBOCK

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SINCE 1912 when Casimir Funk first brought to the attention of the public the hitherto unknown dietary essentials under the collective term vitamines, nutrition experts have felt that they had something tangible to investigate—something the importance of which it was necessary to prove or disprove. As experimentation revealed symptoms attributable to vitamine deficiency, the general public, ever easily impressed by matters unexpected, and matters so vital as to revolutionize the conception as to what constitutes an adequate diet, soon became alarmed. At present it is probably not overstating the situation when it is said that the previously considered all-important attributes of an adequate ration, such as sufficient protein, calories and salts, have probably been slighted by the sudden interest taken in vitamines. Nor is this so very remarkable. Certainly no individuals have been more impressed with the important rôle that vitamines have in the diet than the investigators engaged in this field of nutrition. Only a few years ago students were taught that the body needed energy, to be furnished by carbohydrates and fats, protein, to be furnished by proteins, and inorganic elements, to be furnished by ash. These, together with water, were supposed to constitute the sum total of the dietary requirements of the animal body. Imagine the surprise and chagrin of the nutrition experts when it was found impossible to support the life of an experimental animal, such as the rat, on a ration compounded from these elementary *highly purified* food stuffs. Lack of palatability resulting in insufficient consumption was given as the reason. "How," was it asked, "can an animal maintain itself when the lack of taste to the food leads to loss of appetite?" "Our naturally occurring foods contain esters and ethers which induce better consumption and therefore maintenance." But, on investigation, it was found that a great substantial variation in the taste of the ration by the addition of flavoring extracts of great variety in kind and amount did not improve the nutrition of the animal. Not until there were added small amounts of certain plant or animal tissues or their extracts—now known

1. A pigeon showing a neck spasm in an acute attack of avian beri-beri (polyneuritis) resulting from the consumption of a ration deficient in water-soluble vitamine.

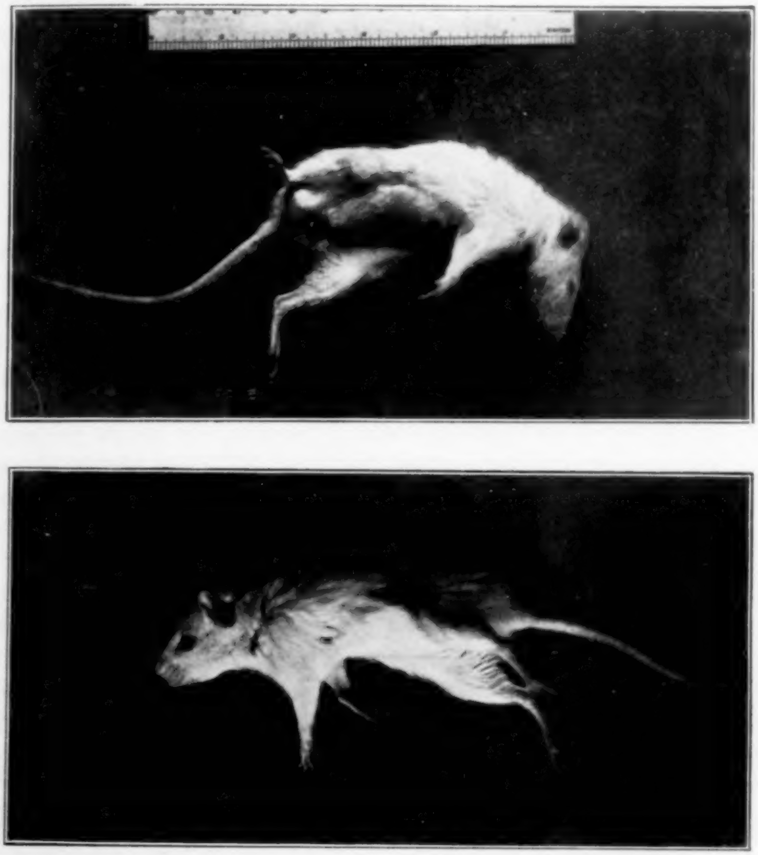
to furnish the vitamines—was it found possible to induce normal nutrition. Certainly the public is to be excused, if, as the result of the enthusiasm of the investigator, it shows undue concern over the vitamine content of the daily diet.

Let us analyze the situation more minutely from the experimental standpoint, so that we can comprehend what is definitely known in regard to vitamines, what physiological disturbances are to be expected if our diet is deficient in them and what with our present mode of living is the probability of a deficiency.

Generally it would be inferred from the term, as Funk implied, that vitamines are substances of an amine nature concerned with vital phenomena. Though certain derivatives of ammonia have been shown to have some of the properties of vitamines, yet of their amine nature there is conclusive proof. Of their relation to vital phenomena there is absolutely no question. Physiologically, vitamines can be divided into at least two types. Both are soluble in water, but only one is soluble in fats. This difference in properties has led to their characterization, respectively, as a water-soluble vitamine and as a fat-soluble vitamine. Though possible, yet in the light of present information it can not be considered probable that either type consists of more than one active component. Chemically, in even an approximately pure form, both vitamines are entirely unknown. Without either kind in the diet, animal life, at least that high in the genetic scale, is impossible.

Curiously enough, the observations of symptoms indicative

of a lack of the water-soluble vitamine in the dietary were made on man himself. In the far east, especially in the Malay peninsula, in the Philippines and in Japan, there has been prevalent a disease known as beri-beri. It is characterized by a loss in weight with muscular atrophy, contracture or paralysis. It may run a rapid course, ending in sudden death, due to heart failure, or it may take on a chronic form. On post mortem there is evidence of more or less edema and extensive degeneration of nerve elements. Though these cases were of quite frequent occurrence, economically this disease was first brought to the attention of the civilized world when, during the Russian-Japanese war, a considerable portion of the Japanese army was incapacitated by its ravages. Fortunately,



2. A young female albino rat suffering from polyneuritis due to a deficiency in its diet of the water-soluble vitamine. Note the abnormal curvature of the back and especially in the one photograph an extreme spasticity. This rat should normally have weighed 120 grams; its actual weight was 54 grams. A rat in this condition without treatment will usually die in 10 to 24 hours.

by this time, experimental investigation had already indicated suitable prophylactic treatment, and prompt improvement and final prevention were brought about by providing for more variety in the ordinary oriental diet of white rice and fish.

Beri-beri was put upon an experimental basis when Eykman, a Dutch investigator working in the East Indies, observed that birds fed exclusively on white rice developed symptoms resembling those of human beri-beri. At first they consume rice readily, but anorexia soon ensues. After a period of a few weeks the onset of the disease is indicated by a tenseness of the muscles of the crop; usually then in the course of twenty-four to thirty-six hours more pronounced symptoms appear. When the bird is entirely at rest these may not be so evident, except for a slight unsteadiness of the head, but upon the slightest excitation the head may be suddenly thrown backwards, the feet forwards and the wings flapped violently as the bird makes an effort to regain its balance. These movements cause it to tumble over and over. In these spasms certain muscles are so exceedingly tense that violent restraint may lead to injury. Not all birds in an experimental lot may show these symptoms, variations in the symptoms being caused by the kind of nerve elements affected in the degenerative processes. Some birds may take on a so-called chronic form where the progress of the disease is so slow that death results primarily from starvation. All acute cases can be promptly relieved by the administration of extracts containing the water-soluble vitamine. Complete alleviation of all symptoms in most violent cases have been seen to result three to five hours after the injection of a few milligrams of a concentrated water-soluble vitamine preparation. A bird in violent convulsions often will preen itself, coo, and strut around in its cage six to ten hours after such treatment.

Experimentally, a nutritional polyneuritis can also be induced in the rat. A lack of the water-soluble vitamine in the ration of the growing rat will soon lead to cessation of growth, then to rapid loss in weight and finally to spasms which terminate in death. The oral administration of the water-soluble vitamine, if the respiration has not become too feeble, will terminate the violent symptoms and lead to complete recovery. If the administration of the vitamine is continued, the animal will resume eating and rapidly regain its health and begin to grow. In certain ways the water-soluble vitamine stands in different relations to the reproducing animal than other food constituents. When the ration of a nursing animal is poor in

3. The same rat 23 hours later after the oral administration of an alcoholic extract of 3.4 grams of wheat embryo. It was now able to sit quietly in normal position and resume eating its former vitamine-deficient ration.

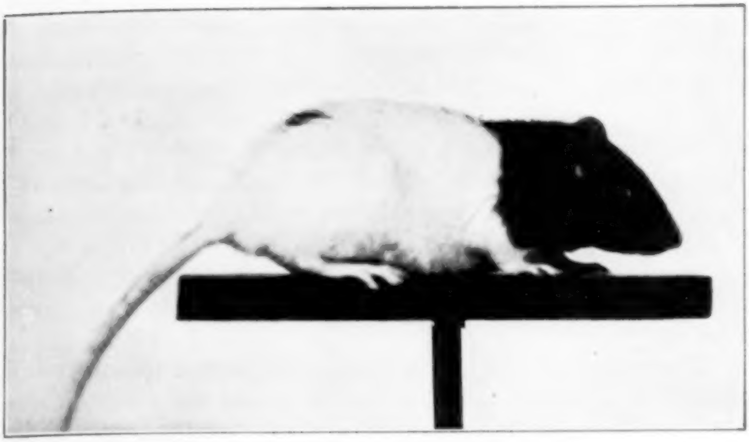
good proteins or poor in certain mineral elements such as lime, normal milk will be produced at the expense of body tissue. Such a process, which sooner or later results in the depletion of the reserve of the mother, gradually manifests itself in her appearance. When, on the other hand, the ration is low in its content of water-soluble vitamine the mother may maintain herself in fine condition and the young will grow, but may suddenly become neuritic and soon succumb.

Deficiency of a ration in the fat-soluble vitamine is indicated by symptoms not so specific or so dramatically manifest. A young rat will fail to grow, and a mature rat will fail to maintain itself just as would happen if there were a deficiency of suitable protein, ash or available energy, but in addition these rats are predisposed to a purulent conjunctivitis which usually leads to permanent blindness. So general is this condition that it might be taken as pathognomonic of this dietary deficiency if it were not for the fact that an indistinguishable form sometimes occurs in animals on other rations. In addition, Osborne and Mendel have found that their rations deficient in the fat-soluble vitamine induced the formation and deposition of calculi along the urinary tract. It is barely possible that these two conditions are related, irritation in the eye socket, due to abnormal secretions, preparing the field for the conjunctivitis. That it is an infection is indicated by its response to proper medication.

As these two forms of dietary deficiency can be easily dem-

onstrated experimentally in the laboratory, one may well ask the question—what is the probability that certain cases of recognized or even unrecognized malnutrition in man may be due to an avitaminosis? With respect to beri-beri under ordinary conditions the danger is not very great, if at all existent. It is only when man so modifies the type ingredients in his diet as to depart from the character of *naturally* occurring food materials that beri-beri has ever been known to occur. The oriental suffered from this malady when he began to demand, for esthetic reasons only, that the prepared rice in his diet should be white. As the hulled rice kernel varies in color from a light yellow to almost black, he proceeded by a crude milling process to grind off this variously pigmented pericarp and thus obtained his white or polished rice. Though his esthetic desires were satisfied, his source of water-soluble vitamine had been dangerously reduced in amount; sporadic outbreaks of beri-beri became common. A similar condition of affairs has been reported in Newfoundland where an almost exclusive subsistence on patent wheat flour during a period of scarcity of other foods caused beri-beri. In the milling process where the aleurone layer and embryo of seeds are removed most of the vitamines are removed as well. It is timely to question the wisdom of many of our food-manufacturing processes not only from the standpoint of removal of valuable salts and proteins, but of vitamines as well. Why feed many of the most vitally necessary food constituents having their origin in the manufacture of our food in superabundance to our stock for animal and milk production and feed ourselves on what may look better

4. The same rat 23 days later kept on the same ration, but given daily the residue of an alcoholic extract equivalent to 3.4 grams of wheat embryo dissolved in its drinking water. The rat now weighed 102 grams. At the present time of writing it is in excellent nutritive condition and still gaining rapidly.



5. A female rat and her young raised on a ration rather low in its content of water-soluble vitamine. She became pregnant and raised a litter of four young to a total weight of 66 grams. The nursing young grew rapidly, but suddenly in one day lost 5 grams in weight and showed periods of great excitability. The next day one was found dead, and the others had convulsions as indicated in the cut. Such young invariably develop into normal rats when nursed by a normal rat on a complete ration; otherwise death ensues rapidly.

but nourishes less? Some of our milling processes have been adopted for economical reasons, as in the case of rice the unpolished grain on storage is very liable to become infected with meal worms and its fats are liable to become rancid, but undoubtedly other means could be found to cope with these difficulties. All food materials making up the greater part of the human dietary so far investigated have shown the presence of a generous amount of the water-soluble vitamine. Lack of water-soluble vitamine undoubtedly has not been one of the determinants which in itself has interfered with man's general progress and development.

There has recently come to the attention of the medical fraternity in Denmark and in Japan an abnormal condition of the eyes, a xerophthalmia, in children fed on pasteurized milk or grain milk-substitutes. Monrad and others have made the suggestion that this is due to an avitaminosis. This hypothesis has been tentatively accepted on the basis of experiments with rats such as previously described and because improvement has been found to result upon adding raw whole milk or cod-liver oil, both of which are rich in the fat-soluble vitamine, to the previous diet. Butter fat is very rich in the fat-soluble vitamine. The dairy cow in the tremendous consumption of rough feeding materials rich in the fat-soluble vitamine performs the act of concentrating it in the food for her offspring.

Man probably can not safely restrict himself to grains as his source of supply of this dietary essential, but needs to supplement them with the actively growing and assimilating parts of plants. Leafy materials such as have been investigated up to the present time have been found to contain this vitamine in large amounts. Some roots also apparently contain considerable amounts.

Because butter fat is very rich in this fat-soluble vitamine and because plant fats and the body fats of animals contain but little of it, much has been said in favor of the use of butter instead of butter substitutes. In full realization that but small amounts of the vitamines are required it must be remembered, however, that butter is wholly absent from the dietary of some and at most constitutes but a small part of the total of food stuffs consumed by most people and while little is known definitely of the fat-soluble vitamine content of other foodstuffs, yet enough is known to indicate that sufficient amounts to satisfy all requirements of the body can be carried by other food materials. It is not necessary to value milk especially on the basis of its fat-soluble vitamine content when it is remembered

6. The same rat 77 days later after having had two more litters, neither of which she kept alive longer than a few days. Though slightly longer haired she weighed 25 grams more and was in good condition. Rearing of the young is a process more exacting in its requirements than either growth or reproduction.

that as a source of protein for the animal it has no equal. For this we have no substitute, for it as a source of fat-soluble vitamine we have.

At one time, there was a tendency to associate etiologically other conditions of malnutrition, such as scurvy and rickets, with a deficiency of specific vitamines. Evidence so far presented does not support this contention. These diseases are undoubtedly associated with a faulty intestinal condition not directly referable to an avitaminosis.

In the present emergency in the economic food situation, it

7. Two male rats of the same age. The one on the right—a normal rat—received a sufficiency of the fat-soluble vitamine in its ration; it weighed 262 grams. The one on the left received but little of the fat-soluble vitamine; it weighed 109 grams. Note the inflammation of the eyes and the incrustation of the ears to which rats on a ration deficient in the fat-soluble vitamine are subject. Both conditions, if not too far advanced, can be improved by suitable medication.

is the duty of all students of nutrition to scan the horizon very carefully for indications pointing the way for rational modifications in the selection of nutriments. An individual so adapted as to be able to digest large amounts of food without digestive or other organic disturbances undoubtedly guards himself against a deficiency of any nutrient in his diet. This, in considerable measure, may account for the great capacity for work shown by some heavy eaters. On the other hand, many people are undoubtedly limited in their performance due to a shortage of a necessary constituent. When the food consumption is large there is little cause for concern, but when it is limited in quantity and in variety it is well to realize that any one of the factors, viz., vitamines, protein, salts or energy may limit a man's capacity for work. It might be said that it is unfortunate that man is not gifted with a sense of perception indicating to him the specific dietary needs of his body. He is either hungry or satisfied and ultimately he feels well or unwell. It is sufficient to say that vitamines are indispensably necessary in the diet, but for normal nutrition, if the individual has the opportunity to select his foods as he desires, lack of vitamines should undoubtedly give no greater cause for concern than lack of suitable proteins or salts. There is cause to look forward with considerable anticipation to the economic results which are bound to come with a fuller knowledge of what constitutes the valuable dietetic properties of many food materials individually and in various combinations.

THE PROGRESS OF SCIENCE

ONE HUNDRED YEARS OF THE AMERICAN JOURNAL OF SCIENCE

In July, 1818, *The American Journal of Science and Arts* was established by Benjamin Silliman, professor, as the title page of the first number states, of chemistry, mineralogy, etc., in Yale College. In the century that has since elapsed, the journal has witnessed and been itself a part in the most notable of all performances, the development of modern science. The present editor, Edward S. Dana, the grandson of Silliman, and like him professor at Yale, including mineralogy and other physical sciences in his field, has done well to issue a centennial number of the journal and himself review its history, while other contributors, who have been active in its work, sketch the history of the sciences covered by it. These articles have been made the basis of seven Silliman lectures, to be published by the Yale University Press, in accordance with the terms of the foundation established by a nephew of Benjamin Silliman.

The advancement of science in the past century and its progress in this country are the more notable if we compare the present situation with the humble and almost naïve beginnings of the *Journal*, and contrast them with other forms of human achievement, as poetry, literature, music and the fine arts, which at most have remained stationary, while our political institutions have progressed so little that they permit wars as devastating as those of the Napoleonic era.

The *Journal* was a modest quarterly, but the "Plan of the Work" with which it opens includes an ambitious medley of subjects which indicates so correctly the situation of science a hundred years ago that it deserves to be quoted:

> This Journal is intended to embrace the circle of THE PHYSICAL SCIENCES, with their application to THE ARTS, and to every useful purpose.
>
> It is designed as a deposit for *original American communications:* but will contain also occasional selections from Foreign Journals, and notices of the progress of science in other countries. Within its plan are embraced
>
> NATURAL HISTORY, in its three great departments of MINERALOGY, BOTANY, and ZOOLOGY;
>
> CHEMISTRY and NATURAL PHILOSOPHY, in their various branches: and MATHEMATICS, pure and mixed.
>
> It will be a leading object to illustrate AMERICAN NATURAL HISTORY, and especially our MINERALOGY and GEOLOGY.
>
> The APPLICATIONS of these sciences are obviously as numerous as *physical arts*, and *physical wants;* for no one of these arts or wants can be named which is not connected with them.
>
> While SCIENCE will be cherished *for its own sake*, and with a due respect for its own *inherent* dignity; it will also be employed as the *handmaid to the Arts.* Its numerous applications to AGRICULTURE, the earliest and most important of them; to our MANUFACTURES, both mechanical and chemical; and to our DOMESTIC ECONOMY, will be carefully sought out, and faithfully made.
>
> It is also within the design of this Journal to receive communications on MUSIC, SCULPTURE, ENGRAVING, PAINTING, and generally on the fine and liberal, as well as useful arts;
>
> On Military and Civil Engineering, and the art of Navigation.
>
> Notices, Reviews, and Analyses of new scientific works, and of new Inventions, and Specifications of Patents;
>
> Biographical and Obituary Notices of scientific men; essays on

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ARTS.

CONDUCTED BY

BENJAMIN SILLIMAN.

PROFESSOR OF CHEMISTRY, MINERALOGY, ETC IN YALE COLLEGE, AUTHOR OF TRAVELS IN ENGLAND, SCOTLAND, AND HOLLAND, ETC

VOL. I.....NO. I.

ENGRAVING IN THE PRESENT NO.

New apparatus for the combustion of TAR, &c. by the vapour of water.

New-York:

PUBLISHED BY J. EASTBURN AND CO. LITERARY ROOMS, BROADWAY, AND BY HOWE AND SPALDING, NEW-HAVEN.

Abraham Paul, printer.

1818.

TITLE-PAGE OF THE FIRST ISSUE OF THE AMERICAN JOURNAL OF SCIENCE.

COMPARATIVE ANATOMY and PHYSIOLOGY, and generally on such other branches of medicine as depend on scientific principles;

Meteorological Registers, and Reports of Agricultural Experiments: and we would leave room also for interesting miscellaneous things, not perhaps exactly included under either of the above heads.

For half a century the *American Journal of Science* remained practically our only scientific journal. Then in 1867 THE AMERICAN NATURALIST was established, followed in 1872 by *The Popular Science Monthly*, of which THE SCIENTIFIC MONTHLY is the editorial successor, and in 1883 by the weekly journal SCIENCE. Simultaneously special journals began to appear: in 1875 the *Botanical Bulletin*, the predecessor of *The Botanical Gazette;* in 1878 the *American Journal of Mathematics*, in 1879 *The American Chemical Journal*, now merged with the *Journal of the American Chemical Society;* in 1888, *The American Geologist*, no longer published, in 1887 *The Journal of Morphology*, and so on, in increasing numbers until to-day the files of our scientific journals fill alcoves of a library. The American Journal of Science is now only one in a large group of journals, but it occupies an important place earned not only by its history but also by its present high standard in the publication of scientific research.

HOURS, FATIGUE AND HEALTH IN BRITISH MUNITION FACTORIES

HOURS, fatigue and health in British munition factories is the title of a Bulletin, No. 221, issued by the Bureau of Labor Statistics of the U. S. Department of Labor as the first of a series of bulletins prepared at the instance of the Council of National Defense for the purpose of giving wide circulation to the experiences of Great Britain, France, Canada and other countries in dealing with labor in the production of the largest quantity of munitions in the shortest space of time. The bulletin contains the reprint of eight memoranda published by the British Health of Munition Workers' Committee which was appointed in September, 1915, "to consider and advise in questions of industrial fatigue, hours of labor, and other matters affecting the personal health and physical efficiency of workers in munition factories and workshops." These memoranda deal with Sunday labor, hours of work, output in relation to hours of work, industrial fatigue and its causes, sickness and injury, special industrial diseases, ventilation and lighting in munition factories and workshops, the effects of industrial conditions upon eyesight.

From a perusal of these memoranda it appears that Sunday labor, in the opinion of the committee, is not profitable and that continuous work "is a profound mistake" and does not lead to increased output; that a system of shifts although impracticable in some cases is to be preferred to overtime, since the latter taxes the strength of workers too severely, results in loss of time because of exhaustion and sickness, and curtails unduly the period of rest; that night work should be discouraged, that output can not be maintained at the highest level for any considerable period if the conditions are such as to lead to excessive fatigue and to deterioration in the health of the worker, with a recommendation that hours should not exceed 56 per week for men engaged in very heavy labor, or 60 for men engaged in moderately heavy labor, while 64 should be a maximum.

The committee's study of industrial fatigue and its causes sums up its own studies of hours of labor, emphasizing the importance of reg-

ularity of hours and of daily and weekly rests made with due consideration of the character of the work performed. In its report on sickness and injury the committee points out certain injurious conditions which should be guarded against as likely to diminish seriously the efficiency of the labor force "To conserve energy and efficiency is, other things being equal, the way to improve output." The medical examination of all workers before employment is recommended, and it is suggested that factories should provide proper sanitary facilities, safeguard machinery, make arrangements for adequate medical and nurse schemes, etc. The value of first-aid is emphasized.

The report on special industrial diseases gives the causes, methods of prevention and treatment for the principal industrial diseases which have been found to affect munition workers. Particular attention is directed to the importance of adequate lighting and ventilation which are absolutely essential for the maintenance of health and comfort and, therefore, the efficiency and capacity of the workers. Special measures to prevent undue strain upon eyesight and to reduce the liability of accidents to a minimum are recommended.

SCIENTIFIC ITEMS

WE record with regret the death of Karl Grove Gilbert, the distinguished geologist of the U. S. Geological Survey; of John Harper Long, professor of chemistry in Northwestern University Medical School; of Stephen Farnham Peckham, known for his work in the chemistry of bitumens; of George M. Searle, formerly professor of mathematics and astronomy in the Catholic University of America; of Richard Rathbun, assistant secretary of the Smithsonian Institution, and of Sir Alexander Peddler, the English chemist.

THE Croonian Lecture before the Royal Society was delivered by Major W. B. Cannon, professor of physiology, Harvard Medical School, on June 20, the subject being "The physiological basis of thirst."—The Wilbur Wright memorial lecture of the British Aeronautical Society was delivered in the Central Hall, Westminster, on June 25, by Professor W. F. Durand, chairman of the American Advisory Committee for Aeronautics, scientific attaché to the American Aviation Mission in Europe, and professor of mechanical engineering, Stanford University, U. S. A. The subject was "Some Outstanding Problems in Aeronautics."

THE American Association for the Advancement of Science and the National Scientific Societies affiliated with it will meet at Baltimore in Convocation Week. It had been originally planned to meet in Boston, but under existing conditions it was thought best to choose a place as near as possible to the main centers of scientific activity and at the present time large numbers of scientific men are working at Washington. It is planned that the meeting will direct its main attention to the service of science in the present national emergency.

YALE UNIVERSITY received by the will of John W. Sterling, of the class of 1864, a distinguished New York lawyer, the residue of his estate, which it is said amounts to fifteen million dollars.—Mr. Hobart W. Williams has given to the University of Chicago property to the value of $2,000,000, part of the income to be used for the development of the school of commerce and administration.

SCIENTIFIC BOOKS

THE ZONE POSTAL RATES

Owing to its national circulation, THE SCIENTIFIC MONTHLY is heavily taxed by the new law imposing zone rates on the advertising parts of second-class matter. This law appears to be unfortunate from the point of view of maintaining national interests and national unity. It is desirable that readers who share this point of view should write to congressmen and senators from their states urging the repeal of the zone law. The question is clearly stated in the following letter from the Honorable Charles E. Hughes addressed under date of June 17, 1918, to the Publishers' Advisory Board:

In answer to your letter, I beg to say:

I prefer not to accept a retainer to appear before legislative committees upon matters of general policy, as in such matters, if I have anything to say, I desire to speak only as a citizen.

I have no hesitation in saying that I regard the zone system of postal rates for newspapers and periodicals, coming under the definition of second-class mail matter, as ill advised. The Commission on Second-Class Mail Matter (appointed in 1911), of which I was a member, considered this question and reported unanimously against the zone system. We said in that report:

> "The policy of the zone rates was pursued in the earlier history of our post office and has been given up in favor of a uniform rate in view of the larger interest of the Nation as a whole. It would seem to the Commission to be entirely impracticable to attempt to establish a system of zone rates for second-class matter. * * *
>
> "Progress in the post office, with respect, both to economy in administration and to public convenience, leads away from a variety of differential charges to uniform rates and broad classifications."

In my judgment the zone system for second-class mail matter is unjust to the publisher and unjust to the public. It not only imposes upon the publisher the additional rates upon a sectional basis, but it makes necessary the added expense for the necessary zone classifications at a time when every economy in production and distribution is most important. It introduces a complicated postal system to the inconvenience of the publisher and public when there should be a constant effort toward greater simplicity. There is no more reason for a zone system of rates for newspapers and magazines than for letters.

Newspapers and magazines are admitted to the second-class postal rates on the well established policy of encouraging the dissemination of intelligence, but a zone system is a barrier to this dissemination. If it is important that newspapers and magazines should be circulated, it is equally important that there should not be sectional divisions to impede their general circulation through the entire country.

We are proud at this moment of our united purpose, but if we are to continue as a people to cherish united purposes and to maintain our essential unity as a nation, we must foster the influences that promote unity. The greatest of these influences, perhaps, is the spread of intelligence diffused by newspapers and periodical literature. Abuses in connection with second-class mail matter will not be cured by a zone system of rates. That will hurt the good no less than the bad, and perhaps some of the best sort of periodical literature will be hit the hardest.

We do not wish to promote sectionalism, and "one country" means that in our correspondence and in the diffusion of necessary intelligence we should have a uniform postal rate for the entire country. The widest and freest interchange is the soundest public policy.

I hope that Congress will repeal the provision for the zone system which is decidedly a looking-backward and walking-backward measure.

Very sincerely yours,

(Signed) CHARLES E. HUGHES

The Scientific Monthly

Entered as second-class matter October 1, 1915, at the post-office of Lancaster, Pennsylvania, under the Act of March 3, 1879

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1918

THE TEACHING OF THE HISTORY OF SCIENCE

By GEORGE SARTON

CARNEGIE INSTITUTION OF WASHINGTON

DURING the last two years I have had to lecture on the history of science before a score of American and Canadian universities. In each university center I have naturally met and discussed with most of the people interested in the subject, which has enabled me to gauge pretty accurately the general sentiment concerning it and to figure the prospects of these studies. The present essay is the fruit not simply of this random experience as a lecturer, but also of my experience as a teacher in Harvard, Columbia, at the University of Illinois and the George Washington University. I propose both to clear up some misunderstandings, the further development of which might be more fatal to the history of science than mere indifference, and to answer a question which has often been addressed to me:

> You always lay stress on the importance of the history of science, as the best way of *humanizing* science and giving to it its whole educational value. But how shall we best do it? How should these studies be organized? And what should be the spirit of this teaching? . . .

The main misunderstanding to be dispelled (I will return to it, but I wish the reader to know from the start where I am aiming) is one which is chiefly bred by professors of philosophy. I have had the privilege to talk with many of these after my lectures, and not a few seemed to be surprised at my statement that the history of science had yet hardly been taught. Why! they themselves had been teaching it in their courses on the history of philosophy. . . . They spoke of Thales, Pythagoras, Democrites . . . they had actually explained the development

of ideas on atomism, heredity, cosmic evolution, etc. . . . What more did I want?—Well, I wanted so much more and I felt that they were so deeply ignorant of the most elementary facts of science, so unaware of their real significance, so innocent of the true spirit of science, that I often gave up explaining anything. But I became more and more convinced of the necessity of insisting above everything else on the scientific foundation of the history of science. The chief requisite for the making of a good chicken pie is chicken; nay, no amount of culinary legerdemain can make up for the lack of chicken. In the same way, the chief requisite for the history of science is intimate scientific knowledge; no amount of philosophic legerdemain can make up for its absence.

The Teaching Must be Experimental and Concrete

> The purpose of the history of science is to establish the genesis and the development of scientific facts and ideas, taking into account all intellectual exchanges and all influences brought into play by the very progress of civilization. It is indeed a history of civilization considered from its highest point of view. The center of interest is the evolution of science, but general history remains always in the background.[1]

Of course, it is the natural, chronological development that we must especially consider, not the deductive and artificial. One of the petty ideas of philosophers is to elaborate a classification, a hierarchy of sciences. They all try it, and they are generally so fond of their favorite scheme that they are prone to attach an absurd importance to it. We must not let ourselves be misled by this. Classifications are always artificial; none more than this, however. There is nothing of value to get out of a classification of science; it dissembles more beauty and order than it can possibly reveal.

As a matter of fact, the most fascinating part of science is the intimate and intricate relations it possesses, not with fanciful doctrines, but with life itself. We can safely say that each new scientific development is due to the pressure of some social need. Of course, we include amongst these needs the insatiable curiosity of certain men, because even this curiosity, disinterested and inopportune as it may seem, is still nothing but a response either to an old problem of nature, or to one arising from new social circumstances. Even the development of mathematics is largely a natural, not a purely logical one: mathematicians are continually answering questions suggested by astronomers or physicists; many essential mathematical theories are but the reflex outgrowth from physical puzzles.

[1] G. Sarton in *The Monist*, XXVI., p. 333, 1916.

Further, the development of science is to a great extent impersonal. It is not the man of genius who leads it—he is only the "star" of the play—the real causes of this development are far deeper and as much beyond our ken as the sources of organic evolution. The different phyla of animals and plants did not successively appear according to a beautiful scheme of gradually increasing complexity; they are all evolving together because they all depend one upon another in many ways. At any stage of development there are all kinds of organisms—some very simple, some very complex—but it can not be said that the latter are more perfect because they all are the solutions of intrinsically different problems. The simplest are apparently as well adapted to their own conditions as the most complex. In the same way all sciences grow together, helping and stimulating one another, with little if any regard for logic and hierarchy; their growth is simply a function of their inner vitality and of the various needs of life.

The development of science is an organic development. We must study and teach it as such and not otherwise. Our teaching must be as unphilosophical and as unscholastic as possible. The few serious courses that have been thus far devoted to these studies, here and abroad, have been, with the possible exception of Mach's lectures, far too philosophical, I mean—far too prone to premature generalizations. In the case of France, this is due to the influence of Auguste Comte and more generally to the French love of system. In the English-speaking world, the influence of the positivist school has been working in the same direction. More recently the very learned and massive publications of John Theodore Merz have accentuated this ratiocinating tendency in the most disastrous way. His "History of European Thought in the Nineteenth Century," enjoying as it does a kind of monopoly, is unanimously praised, especially by those who would make us believe that they have read it. This book certainly conceals a considerable amount of material, but it is so prolix and discursive that its rich substance has to be almost entirely redigested to be of any great service.

Abstract as it is, science is but an outgrowth of life. That is what the teacher must continually keep in mind. If he seeks his inspiration in any philosophical system instead of letting himself be guided by the plain realities of scientific development, he may produce books that will interest philosophers, but he is lost as a historian. On the contrary, let him follow the lead that I am giving. Let him explain the development of science, as of something living and growing like an animal or a plant, answering to the stimuli of its environment; let him

show that each problem of life releases a new train of scientific problems, and that all these trains interfere one with another and continually give birth to new discoveries and arrangements —and he will soon give to the student the feeling that science is not a dead system—the excretion of a monstrous pedantism —but really one of the most vigorous and exuberant phases of human life. Science has always been growing and changing as it does even now. The teacher must continually strive to increase the intimacy of his disciples with this rich inner life of science. Of course, this will only be possible if he be himself on intimate terms with it. But if he succeed in doing this, his teaching will certainly prove interesting and stimulating.

These are the two alternatives: either the course on the history of science will sooner or later degenerate into a new course of philosophy, and its generality and simplicity will give the student a false sense of knowledge, or it will be, as I say, experimental, concrete, matter of fact.

I do not say that generalizations must be avoided, but simply that they must be reduced to a safe minimum and only offered to the student when all the facts of the case are well understood by him.

These facts are of two different kinds: historical and scientific. The teaching of the history of science must be essentially the interpretation of these two sets of facts. Let us now consider how better to explain each of them and how to harmonize the simultaneous teaching of both.

The Teaching of Historical Facts

It is in the historical part of the teaching that the connections between science and all other human activities are made manifest. Hence this part is the most important from the pure humanistic point of view. The basis of any historical interpretation, of course, is the arrangement of all interesting facts in a chronological sequence. This implies painstaking and monotonous research work, a drudgery from which most scientists would fain escape. But this work being fundamental can not be too accurately done, even in those cases where historical details may seem of trivial importance. Accuracy is to the scholar what discipline is to the soldier: it must be implicit or it is not worth anything.

I have already shown elsewhere that the development of science is intimately connected with every other human development; there are continuous interactions, for example, between science and art, science and religion, science and industry, science and law, . . . not to speak of the influences revealed by gen-

eral or political history. It is the historian's business to disclose these various and continuous interactions, and so to bring into greater relief the organic development of science. He will show that this development is really the culmination of human achievement. He will lay particular stress on the relations of this greatest of human tasks with two others which are almost as important; the creation of beauty and the development of social institutions.[2] Indeed, it should be obvious to all that it is these developments, but chiefly the development of knowledge, upon which the history of human progress should be focused. To make this clear, the teacher will lose no opportunity of showing the cumulative and progressive, also the international character which is specific to science.

The center of gravity of historical studies must be displaced. As a matter of fact it has been moving all along in the direction which I indicate: at first it was dynastic, then military, national, political, institutional, social . . . it is now high time that it become really scientific. Human achievement in the realms of knowledge, beauty and justice is the real thing; the rest is merely anecdotic. Of course, most historians can not be expected to subscribe to this, and many will imperturbably follow their own lines without even trying to know something of the evolution of science. There is no objection to that, any more than there can be any to the simultaneous existence and to the collaboration of organisms having reached different stages of development. Protozoa, insects, birds and men . . . each is doing his little bit. The only thing which will have to be stopped is the old historian's belief that his medieval point of view is really the most catholic; also his absurd pretense to control historical studies.

It is well to give due importance to the biographical side. There is no better way of stimulating the student's interest than to narrate with sufficient detail the lives of those heroes to whose efforts and sacrifices we owe the best of our civilization. And if they really had to suffer because they were so much ahead of their time, and too little concerned with the requisites of every-day life, if they were not understood and died unrewarded, it becomes the historian's sacred duty to redress

[2] However important and impressive these two developments may be, they are not just as important as the development of science because they are less specifically human. Some animal societies have reached a high stage of perfection; it may be that it is less the lack of solidarity than the lack of positive knowledge, of tools, that has prevented them from going even higher. As to beauty, there is an infinite amount of it outside of man.

this injustice by explaining in full the greatness of their work, and making them live again, forever.

The Teaching of Scientific Facts

Important as it is, the historical side of our studies must evidently be subordinated to the scientific side. There would be little sense in explaining the history of something which would not in itself be clearly understood.

And yet this is perhaps the weakest point of most courses on the history of science, and one can not help shivering at the thought of what would happen if such courses fell into the hands of scientifically untrained philosophers. It is a well-known fact that people having no direct knowledge of science are almost bound to make fatal mistakes on essential points, often on those which appear to be extremely simple.

Now, if a course on the history of science were to become the vehicle of false or inaccurate scientific ideas, it would be more detrimental than useful. Hence the professor of general history should forbear from dealing with scientific facts of which he is not able to give an accurate and circumstantial account. As to the instructor on the history of science, he should not undertake to tell the history of any scientific idea, without making sure of his ability to explain the full signification not only of this idea, but also of each step which led to its discovery. He must be able to do this in the most concrete and specific way.

It follows from this that he should be given all the paraphernalia necessary for the explanation of the scientific facts involved, such as maps, charts, pictures, models and various apparatus. How can it be possible to interpret—say—Galen's or Vesalius's anatomical discoveries (also their mistakes) or the discovery of the circulation of the blood or of the nervous function, without having at least some good anatomical models or drawings upon which to point out the various details alluded to? With the proper models the teaching is easy, clear, convincing, interesting; it becomes hopelessly dry, confusing and tiresome without them. It is noteworthy that these models and charts are necessary both for introductory and for the most special courses. In the case of elementary courses, however, they are especially useful in the avoidance of too many technical terms. I have borrowed my examples from the field of biology, but the same thing is true of any other department of science. How shall I properly explain the development as well of primitive tools, as of the steam engine or the dynamo—without models or pictures? of geographical discoveries, without maps? In the

latter case, maps are not even sufficient. When I narrate the discovery of America, I should like to be able to explain exactly how Columbus navigated. Therefore I should need a cross-staff, an astrolabe, a primitive compass, a portolano and some early printed astronomical table. It would not be necessary, of course, to have original instruments and copies could be easily obtained at a relatively low cost. Does not any one see that such teaching of the geographical discoveries would have infinitely more sense and import than the usual vague and literary description?—I know that the literary people will insinuate that I would destroy all the romance of these adventures. I do not believe in the romanticism of ignorance. What is truly heroic, pathetic, grand, would certainly be put in stronger relief by such explanations. If the early navigators had been blind fools, we could not call them heroes; they were conscious of their purpose and of the dangers to be encountered and they had to pool all their knowledge and energy to fight against nature. The literary people have told but a small part of their story.

Models and instruments would not be less needed for the teaching of more abstract sciences, even of mathematics. To elucidate the development of the latter, its cultural value and its relation to other sciences, it is well to be able to show ancient instruments—for example, abaci, arithmetical machines, slide rules—not to speak of geometrical models and of more complex mathematical machines which become almost indispensable. Will not a lecture on the work of Fourier, for example—either in a course on the history of mathematics or in one on the history of physics—gain considerably in interest if it be possible to demonstrate its further applications by means of some kind of harmonic analyzer?

It is not less necessary, whenever the subject lends itself to it, to make some fundamental experiments. It would be the more necessary if the students have less scientific training. It should not be permissible to speak of Galileo without making some very simple experiments on gravity, nor to speak of Huygens, without illustrating in a similar way the laws of centrifugal force. No amount of verbal explanation can ever replace such experiments. In a general course on the history of science, all the fundamental facts of physics, chemistry, biology, should be demonstrated experimentally whenever it is possible to do so without too much trouble. I may add that if it became a common practice to illustrate historical courses by experiments, a greater accuracy in the statement of scientific facts would be automatically secured.

The scientists teaching the history of their own science in their own lecture hall, if they are often handicapped by a serious lack of historical training, at least have the enormous advantage of being able to make the necessary experiments with greater ease and effectiveness. What such courses often lose in historical accuracy they gain in scientific precision and experimental pointedness.

I do not hesitate to say that without experiments the very best of these courses on the history of science is lost. The experiment is not simply necessary, as in a regular scientific course, to prove the fact to the student's senses. It is of even greater importance in our case, to introduce him to the handicraft part, the most living part, of science. This can hardly be explained with words. The student must be made to understand that science is not simply a product of the brain, but also of the whole of our muscular and sensual experience. To know a science does not mean simply to remember a certain number of facts and principles duly classified; it implies far more an intimate acquaintance with various methods and apparatus into which a great deal of scientific thought is so to say crystallized. Even in mathematics, there is room for a certain amount of handicraft of a subtler kind—the almost automatic handling of certain formulæ and symbols.

It is essential for the student to understand this to the best of his ability, because it is only on this condition that he will be able to watch the inner growth of science, and to see it, so to say, in the making. Great discoveries have been made chiefly by men whose entire attention was concentrated upon limited problems and specific experiments, then upon certain material details of these experiments. That is the real heart of science; the spring of its eternal youth.

Any philosophical or literary history of science necessarily fails, and will ever fail, to show that. As a matter of fact, no history of science has ever been written from this point of view —none that I know of, not even Ernst Mach's admirable history of mechanics, although he has come considerably nearer to this ideal than any other author.

Equipment

Lectures on the history of science illustrated by experiments and various demonstrations can not possibly be given in an ordinary lecture hall. There are three methods of solving this practical difficulty.

The first is to have the lectures delivered in the various scientific halls where the needed implements would be at hand.

Lectures pertaining to anatomy might be given in the medical school; lectures on Galileo, Newton or Helmholtz in the physics building, and so forth. This method would be the source of so many conflicts and misunderstandings, even if the different halls were sufficiently near to each other, that we may just as well dismiss it as impracticable.

There remain the two other solutions: the ideal one is to provide for this teaching a special lecture room, completely equipped for the making of simple physical, chemical and biological experiments. If this was found to be too expensive, the historical courses could be given in any other scientific hall. The instructor would then deliver most of his lectures in this hall, but would have to take his flock to other halls whenever necessary. It must be noted that even if a well-equipped hall were placed at the lecturer's disposal, he might still find it necessary to give once in a while a lecture in another building, in the observatory, for instance, or in one of the university museums.

It is not necessary here to describe the ideal lecture hall which I have in mind; it would simply combine the main features of ordinary physical, chemical and biological amphitheaters. The chief difference between my lecture hall and these amphitheaters would lie less in the hall itself than in the series of instruments and models collected either around it or in neighboring rooms. There should be sets of geographical and historical maps; also anatomical, zoological, botanical, geological . . . charts and models. In short, the instructor should be enabled to fully interpret each scientific fact to which he would refer. A collection of portraits of the great scientists would also be desirable, but this is less essential. It would be necessary to have a good set of copies of primitive and ancient instruments: early types of armillary and celestial spheres, microscopes, telescopes, celestial machines, alembics, surgical and obstetrical instruments. . . . Most of these early instruments being rather simple, the making of copies would not be very expensive; it would certainly be far less expensive than most of the models or specimens used in the teaching of biology and natural history. Many antiquated instruments might likely be found in the collection rooms (if not in the attics!) of the scientific buildings of the oldest universities, and, I surmise, would gladly be given or lent to the new department for further and better use.

I must limit myself here to these general indications, but I propose to publish subsequently a more detailed description of

the lecture hall with a tentative list of the maps, charts, models and instruments which would be most urgently needed.

Previous Work in the Same Direction

I do not know of any general course on the history of science, anywhere, which is conducted along the lines which I have indicated. Most of the courses of which I know are to a large extent philosophical courses and lack both historical and scientific concreteness and accuracy.

But something nearer to what I have in mind *may* have been done in the teaching of the history of special branches of science, especially medicine. Courses on the history of medicine have been delivered in many European and American universities, generally by one of the professors of the medical school speaking in his own auditorium with plenty of illustrative material close at hand. In this case, however, there is little opportunity for experiments, except on the occasion of some physiological digression. I must also refer to the little mathematical museum which Dr. D. E. Smith has organized in Teachers College, Columbia University, close to his lecture room. Almost all the objects exhibited are original implements wherewith to illustrate the development of mathematics, not simply in Europe, but also in India, China and Japan. Dr. Smith uses extensively his treasures in his lectures on the history of mathematics, and it was my own privilege, thanks to his courtesy, to be able to use them too when I lectured at Columbia in the summer of 1917. This strengthened my belief that there is no better way of impressing upon the student's mind the relations of abstract mathematics to reality.

As to the physical and biological sciences, for the historical interpretation of which so much illustrative material and so many experiments would be needed, I do not know of any course in which such demonstrations have been actually carried out. The reader will surely think of Ernst Mach, who was professor of inductive philosophy at the University of Vienna from 1895 to 1901. I have no definite information about his method of teaching; I do not know to what extent his courses were experimental. But as Mach had become more and more interested in psychological rather than historical research, it is likely that his teaching was very different from the one of which I am thinking.

General Science

The development of science has become so multitudinous and luxuriant in the nineteenth century, still more in the twentieth;

its complexity, the wealth of facts garnered all over the world, is increasing at such a terrific rate that it is no longer possible to contribute much to its progress unless one concentrates one's efforts and intelligence upon the exploration of a particular field. Every day the field which the average scientist may hope to till fructuously is becoming smaller, and thousands of men are doomed to spend their lives within a very restricted intellectual horizon. However necessary these human sacrifices may be for the advancement of science, they are nevertheless befraught with perils; nay, if they be not compensated in some way or another, they may endanger the whole fabric of civilization.

The only remedy is that which has already been applied in other departments of human activity, in the industrial realm for instance. There also have an increasing specialization and standardization become conditions of success. But business men, who never run the risk of losing touch with reality, have quickly grasped that if no corrective were brought to this extreme specialism, the loss due to disintegration would soon offset the gain in efficiency. Hence, they will no longer allow the creation of new departments or specialties without providing at the same time for some kind of coordinating agency. In the same way, the more most scientists become intensely specialized, the more urgent it is that at least a few devote themselves exclusively to the coordination and synthesis of the whole work. This new specialty, that is the study of general science, is the only means of avoiding the disintegration of the whole and the impoverishment of the scientific spirit.

This study, which many scientists would hardly dare approach, is not necessarily more difficult than any other special study; it is different; it requires a different training, that is all. The men devoting themselves to it would be able to stand in stead of the specialists, to guide them outside of their own garden, to prepare comprehensive surveys, but what is even more important, they would be able to teach the young before they specialize and to give them a broad and solid scientific basis, which would later enable them to keep in touch with the rest of the creative work of the world, and to escape from their prison whenever they would wish to. This teaching would remain an inspiration to them throughout their life.

How should we organize this synthetic teaching? The most natural method is certainly the historical one. However specialized and distant the various ramifications of science may now be, they have all originated from the same trunk. All sciences have grown together, the progress of each promoting the

others and releasing, so to say, new series of thought and inventions all around. To disentangle the apparently overwhelming intricacy of modern science, it is enough to study its heredity.

A concrete, experimental course on the history of science is the best imaginable course of general science, the best introduction to more advanced and special scientific research.

This seems clear enough, but I can not leave the subject of general science without dispelling a grave misunderstanding which obtains in many parts of this country. It is due to the fact that the words "general science" are frequently used with a different connotation from the one which I give to them. What I mean by them is the general fabric of science, the cardinal facts and ideas of each science, and chiefly their interrelations, their points of contact, their relative degree of perfection, the light they throw upon each other, also the view of the universe which is the result of their combined advance. Now I have here before me a very remarkable text-book edited by Frederic D. Barber.[3] It contains an extraordinary amount of information, clearly and simply presented, about most scientific problems which his environment might suggest to any intelligent youngster. The authors have a perfect right to call this book "a first course in general science," inasmuch as it is not dealing simply with physics, chemistry or biology, but with all these branches of science. Yet it is clear that "general science" is here given a very different meaning from my own. It is general science to be sure, but *everyday* science, not *fundamental* science.

The two points of view are radically distinct: the former is practical, utilitarian; the other is theoretical, esthetical, idealistic. From the point of view of everyday science, for instance, it is very important to have sufficient knowledge of the mechanism of an internal combustion engine to be able to handle it without danger or waste, but one may be very familiar with such an engine and yet not know the principles of thermodynamics. On the contrary, from a historical and philosophical point of view it is the knowledge of these principles which is supreme. So also, for him whose material needs must be satisfied as quickly as possible, it is essential to obtain from the beginning some rudimentary knowledge of the functions of his own body; but for one who has time to make his survey of nature in a more leisurely way, it is wiser to grasp first the fundamental principles of physiology and of course it will be easier

[3] "First Course in General Science," by F. D. Barber, M. L. Fuller, J. L. Pricer and H. W. Adams. New York, Henry Holt, 1917.

to lay them bare in the simplest organisms than in such a highly differentiated structure as the human body.

I do not mean to disparage the utilitarian conception of "general science." I am entirely in sympathy with the idea of diffusing clear information on the scientific substrata of everyday life. But neither can it be validly objected to me that courses in general science, such as I propose to establish, already exist, because the courses so-called answer a purpose altogether different from mine. It would be regrettable that such confusion were allowed to persist, and hence I would suggest to call the courses which I have in mind courses on the history of science—a well-grounded designation inasmuch as the method of approach would be essentially historical.

The teaching of the history of science is exposed to two chief dangers each equally to be avoided. The philosophic danger, that is, premature abstraction and generalization, and the utilitarian danger, that is, premature application. Both imply in different ways a serious lack of accuracy; but besides, the former entails a lack of contact with reality, a lack of life. The latter implies a misconception of the essentials of science, a lack of appreciation of its disinterested spirit and of its serene beauty. If the former evil were not sufficiently eschewed, the teaching would be of very little use; on the contrary, if it were too utilitarian, it would have no real educational value.

Typical Program

How then should these courses on the history of science be organized in a large university? I consider that it would be in general sufficient to offer three courses each year. First an introductory course on the history of science throughout the ages. The outline of this course could not vary considerably from one year to another. Secondly, two special courses of which one would be devoted to the history of a special science: physics, chemistry, astronomy, biology . . . and the other to the history of science and civilization at a special period. The latter course would simply be an anticipation of what all courses on general history will be when the literary supremacy passes, a history of civilization focused upon the development of knowledge and social institutions. These special courses should be changed every year, so that students especially interested in them could achieve complete studies in a cycle of three or four years.[4]

[4] The nearest approach to this was made in Harvard. Dr. L. J. Henderson has given there since 1911 a most stimulating course on the history of science. To this general course, I myself added from 1916 to 1918, four

To deliver these three series of lectures, and possibly to direct the activities of a seminary and the research work of advanced students, at least two instructors would be needed. Of both, at least the one in charge of the two special courses should be a specialist, having no other duty than to know and teach his subject as well as possible. His task would still be considerable, as there remains a considerable amount of pioneer work to be done. The writing of a text-book on the history of most sciences is still very much of a venture. There are not yet pedigreed text-books, embodying the accumulated labor of many generations of scholars.

One might ask how far down the history of each science should be carried on. It is not possible to give a general answer to this question. For one thing, neither have the different sciences progressed at the same rate, nor are they equally esoteric; whereas it is out of the question to teach the history of mathematics in the nineteenth century except to advanced mathematical students, the most recent geographical discoveries can be explained almost to any educated person, and nineteenth-century physics or chemistry, to any student having taken only one elaborate encyclopedic course on these branches. The special training of the instructor should also be considered. I assume that he has had a serious scientific training (both theoretical and experimental), but this training may have been chiefly physical, or chemical, or biological. He should be expected to teach the nineteenth-century history of the sciences which he best knows, not of the others.

It is noteworthy that the teaching of the history of modern science is anyhow of a nature very different from the teaching of ancient science. For the latter the main difficulties are historical; for the former, especially when it comes to nineteenth- and twentieth-century science, they rather lie in the statement of the scientific facts themselves. The original documents of nineteenth-century science are generally well known and easily accessible; most scientists have the greater part of them in the sets of periodicals of their laboratory. Hence, the teaching of the history of a branch of science in recent times could often be safely entrusted to a scientist cultivating this particular branch and having a sufficiently acute historical and philosophical sense. This will be even more true when good text-books on the development of nineteenth-century science will be available.

It would be expedient, however, to expect the regular professor of the history of science to devote once in a while a course

special courses. But facilities lacking, none of these five courses was experimental nor as concrete as it should have been.

of lectures to nineteenth-century science, in order to oblige him to keep in touch with living problems. This is essential to ensure the soundness of his teaching.

Local conditions also should be considered. For instance, a university in which the physical department is especially strong and draws a great number of students from all over the country should organize regular courses on the history of physics and induce the advanced students to attend them. In Belgium no one can obtain a doctor's degree in any science without having passed an examination on the history of this science. There is much wisdom in this, although I do not generally believe in examinations.

At least the student should be made to understand the necessity of attending such a course, not because he needs it from a purely material point of view, but because this would form an essential part of his educational background and would help him to appreciate the signification of his own work and its relations to the work of his fellowmen. It is not enough for him to become a clever physicist; he must become, to the limit of his propensities, a generous and broad-minded man. There are only two ways of shaking one's innate narrow-mindedness and provincialism: to move in space or to move in time. One is travel, the other history; both should be periodically resorted to.

Conclusions and Various Remarks

The history of science, to be of any service, must be constantly based on the safest and most complete historical and scientific knowledge. It then provides the most natural and most illuminating interpretation of general science. There is no better way of revealing its disinterested spirit and its supreme beauty; therefore no better way of giving to any scientific teaching its full educational value. A course on the history of science given by the right teacher at the right moment to the right student would constitute his supreme humanistic initiation.

It can not be too often repeated that the value of this teaching will largely depend upon the soundness of its scientific foundation. If it became too philosophic or literary, if it fell into the hands of people knowing science only in a superficial way, the result would inevitably be a falsification of science, with its logical sequences of misunderstandings and verbal quarrels. The course would then be really dangerous, as it would give the students a false illusion of knowledge. I insist that non-committal accuracy is not sufficient; the teaching must be precise and concrete; if not, the result would be neither science,

nor literature, but a mongrel thing,—althogether bad. The chief purpose is to interpret the scientific spirit and methods: this can only be done by one having intimate acquaintance with the subject. Literary people and most philosophers are constitutionally unable to understand scientific methods and values. To entrust such courses to them would be to betray our ideal.

Neither should these courses be open without discrimination to any student. It must be kept in mind that the history of science can not be in itself a complete introduction to science. There is no short cut to scientific knowledge. The only way of attaining it is to study it systematically, with brain and hands. No student should be admitted before having successfully taken at least one laboratory course.

The more science they already know, the more would the students enjoy these lectures. They would supply to them the best recapitulation of the scientific facts and principles with which they would already be acquainted, from a novel and higher point of view.

Such historical courses should be considered, indeed, as a reward: the reward of the traveller who, having reached a stage of his long journey, looks down behind him along the slopes of the mountain upon which he has been climbing. The sun sets; his legs, his whole body, are tired but he thoroughly enjoys the well-deserved rest and the broad prospect which he has won. This is exceedingly sweet and cheering; truly, a great reward. . . .

The ultimate aim is to humanize science, and so to give to it its due part of the educational influence which has remained thus far by sheer inertia the monopoly of the so-called "humanities." Hence, the establishment of courses on the history of science, such as I understand them, will sooner or later entail an educational revolution. I have explained elsewhere, for instance, that it will oblige history to move its center of gravity. The history of civilization will be focused on what is most permanent, progressive and specifically human in the development of the race.

It will also procure the means of solving the old controversy "science *vs.* the humanities"—the modern visage of the ever-recurring contest between scholasticism and original and creative thought, the endless struggle between ever-rampant superstition and positive knowledge. The only cure of endemic scholasticism is experimental science.

We are not intolerant of the endeavors of the literary people, however; we love beauty, even the special form of beauty which they worship, as much as they do. Indeed, we have to